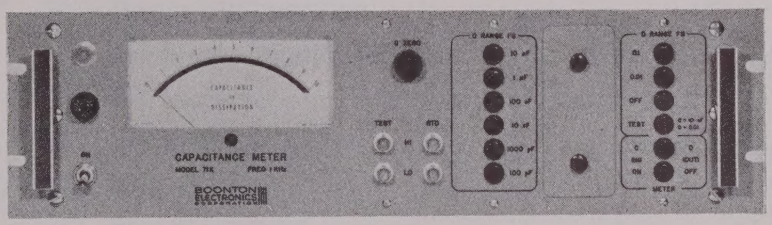
INSTRUCTION MANUAL

for

CAPACITANCE METER

MODELS 71K, 71K-S1, & 71K-S2 (1 kHz)



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SECTION I

SPECIFICATIONS

Capacitance Measurements (3-terminal)

Range:

71K & 71K-S1 ..... 0 to 10 μF in 6 decade ranges

71K-S2 ..... 0 to 1 μF in 5 decade ranges

Accuracy ..... $(0.2 + \frac{1}{Q})$% of reading + 0.01% fs

Meter ..... $(1 + \frac{1}{Q})$% of reading + 1% fs

Where Q = Q of test specimen

Resolution 0.1%

Meter 0.25%

Dissipation Measurements

Range ..... 0. to 0.1 in 2 decade ranges

Accuracy ..... 2% of reading + 0.0005

Meter ..... 2% of reading + 0.0005 + 1% fs

Resolution ..... 1% of reading

Test Signal

Frequency ..... 1 kHz, ±1%

Level:

71K ..... 1 volt (nominal) ±5%

71K-S1 ..... 500 mV (nominal) ±5%

71K-S2 ..... 2 volts (nominal) ±5%

Stability 0.1%

Test Capacitor

Capacitance ..... 10 nF ± 0.1%

Dissipation ..... 0.01, ± 1, %

Q 100

Specifications (contd)

Power Requirements	117 V, ± 10%; 60 Hz
Power Consumption	50 watts
Dimensions	5-1/4" h x 19" w x 10-1/2" d
Weight:	
Unpacked	17 lb
Packed	30 lb

SECTION II

GENERAL DESCRIPTION

2-1 INTRODUCTION

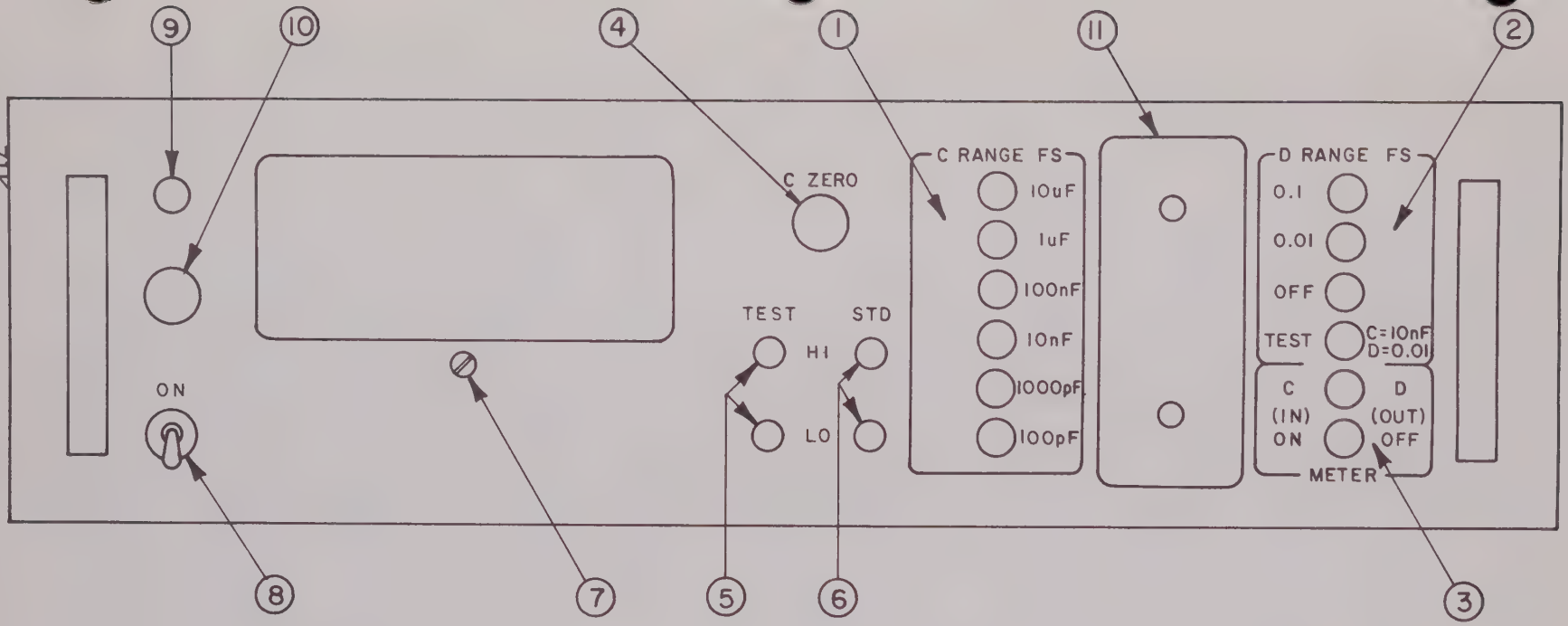
This instruction manual describes Capacitance Meter Models 71K, 71K-S1, and 71K-S2 and contains instructions for their operation and maintenance. Unless otherwise indicated, all information in this manual applies to all three models which are referred to as the Capacitance Meter and the instrument throughout this instruction manual.

2-2 DESCRIPTION AND PURPOSE

The Capacitance Meter is a self-contained instrument used to perform direct (3-terminal) measurements of capacitance (C) or dissipation (D) at 1 kHz. All controls and indicators required for operation are mounted on the front panel (Figure 2-1). The rear panel contains an ac power cable, a set of test terminals that are in parallel with those on the front panel, a dc analog output receptacle, and an interface-control receptacle. The two receptacles provide outputs and interface connections that are compatible with the requirements of Boonton Electronics capacitance test systems. The interface requirements for any other system should be discussed with the Automated Products Division of the Boonton Electronics Corporation (see address on front cover).

2-3 DIFFERENCES IN MODELS

Models 71K, 71K-S1, and 71K-S2 are identical except for the output-voltage level of the 1 kHz test oscillator and the capacitance measurement range, as indicated in the Section I specifications.



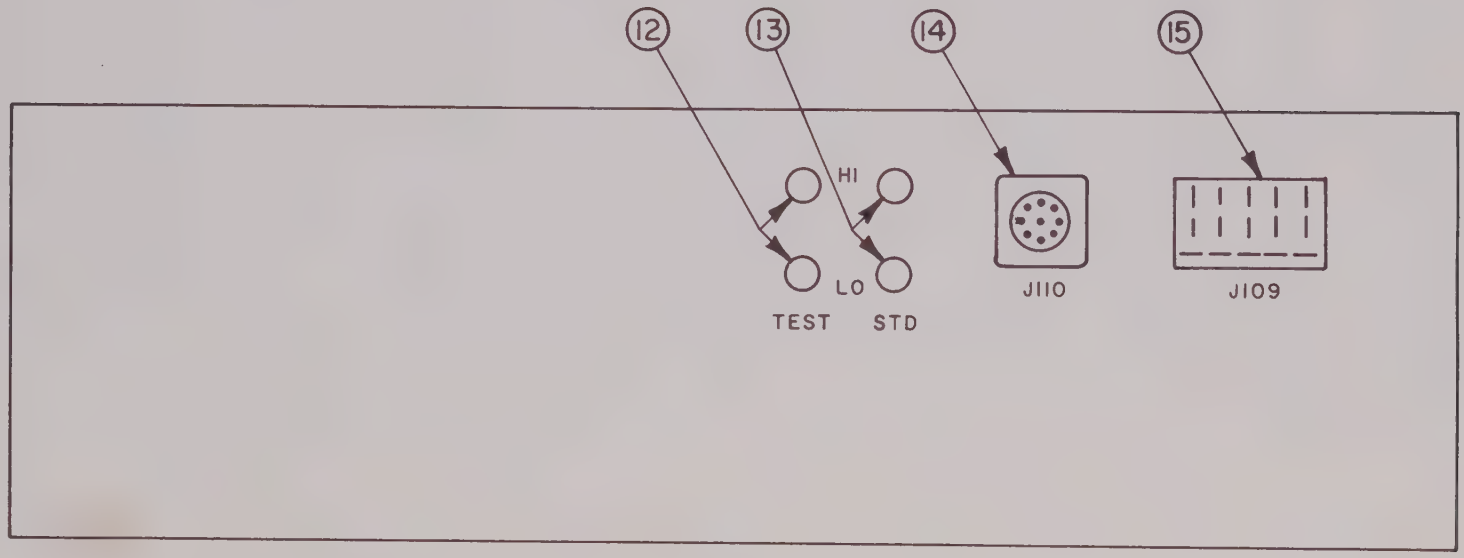


Figure 2-1. Capacitance Meter Controls and Indicators.

2-4 DESCRIPTION OF CONTROLS AND INDICATORS

a. Front Panel (Figure 2-1).

(1) C RANGE FS. Six push buttons (five in 71K-S2) used to select the full-scale capacitance measuring range, as required.

(2) D RANGE FS. Four push buttons in this group provide the following functions:

Dissipation range select: The top two push buttons select either D = 0.01 or D = 0.1 fs ranges.

Dissipation test disable: The OFF push button disables the dissipation measurement. This push button is interlocked with the above two.

TEST: When the TEST push button is depressed, it connects a 10 nF capacitor with a dissipation of 0.01 across the test terminals. This test capacitor is normally used to check dissipation measurement on the 10 nF and 100 nF ranges. This capacitor is initially adjusted to 10 nF $\pm$0.1% and D = 0.01 $\pm$1%, but is not intended as a long-term capacitance standard.

(3) METER. Two push buttons provide the following functions:

Select C or D Measurement: The push button marked C/D switches the meter to read either capacitance or dissipation, in the following manner:

Push button in - meter reads capacitance.
Push button out - meter reads dissipation.

METER ON/OFF: The push button marked ON/OFF enables or disables the meter indication as follows:

Push button in - enables the meter circuit
Push button out - disables the meter circuit.

(4) C ZERO. Provides means for balancing out capacitance across the TEST terminal (up to approximately 50 pF) contributed by exposed terminations of connecting cables, test fixtures, etc. Its range may be increased by attaching an external capacitance to the STD terminals, as described in Paragraph 3-6.

NOTE:

This is a dual ratio control which adjusts a variable capacitor having a full 360° of rotation. The C ZERO control turns easily for about 270° of rotation, and then the torque requirement increases sharply as the control shifts from a 36:1 fine ratio to a 6:1 coarse ratio.

(5) TEST Terminals. HI and LO BNC connectors used to connect test specimens. Measurements may be made either locally or remotely by means of coaxial cables.

(6) STD Terminals. HI and LO BNC connectors. These connectors are used for making differential capacitance measurements, extending the measuring range upwards, or extending the range of the C ZERO control. A given capacitor connected to the TEST terminals produces an accurately calibrated upscale reading. Attaching the same capacitor to the STD terminals causes a comparable downscale reading. The limitations on the use of the STD terminals are outlined in Paragraph 3-7.

(7) Mechanical Zero. This screwdriver-adjust control is used to mechanically zero the meter pointer. Mechanical zero should be checked with the meter circuit disabled.

(8) Power Switch. Controls ac power applied to the Capacitance Meter.

(9) Pilot Light. Glows when the Capacitance Meter is energized.

(10) FUSE. Protects the instrument against short circuit and overload damage. Replace fuse by rotating cover counterclockwise and withdrawing fuseholder.

(11) Cover plate. Provides access to individual range-adjustment controls. The cover plate is removed by withdrawing the two black nylon plungers. The controls under the plate are adjusted during periodic calibration. They should not be adjusted during normal operation. To reinstall the cover plate, insert the nylon retainers into the proper front-panel holes, and push the plungers in until they snap into place.

b. Rear Panel (Figure 2-1).

(12) TEST Terminals. Rear-panel extensions of the front-panel TEST HI and LO BNC connectors; identical in function to the front-panel terminals.

(13) STD Terminals. Rear-panel extensions of the front-panel STD HI and LO BNC connectors; identical in function to the front-panel terminals.

(14) Analog Output Receptacle (J110). Provides facilities to connect dc analog outputs from the Capacitance Meter to external equipment.

(15) Interface-Control Receptacle (J109). Provides facilities to connect interfacing equipment so that the Capacitance Meter supplies range information and control functions.

NOTE:

The analog outputs and control functions of receptacles J110 and J109, above, are intended specifically for the Boonton Electronics Model 54A or 55A Capacitance Reference, which are used in Boonton Electronics capacitance test systems.

SECTION III

OPERATING INSTRUCTIONS

3-1 INITIAL INSTALLATION

a. Unpacking. On unpacking, inspect the instrument for possible damage in transit. If the instrument is damaged, contact your local sales engineering representative or the factory (see title page for factory address) for further instructions. If no damage is found, the instrument may be put into service in accordance with the paragraphs below.

b. Mechanical Zero Adjustment. With the instrument in a normal operating position and the power switch at off, check to see that the indicator needle rests at zero. If necessary, adjust the mechanical-zero screw until the meter needle rests at zero.

c. Turn-on and Warm-Up Procedure. Plug the instrument into a power source of 117 V (±10%) 60 Hz and turn on the power switch. (The pilot lamp should glow.) The instrument may be operated immediately after turn-on. For best accuracy, however, allow a half-hour warm-up period.

d. Initial Installation Checks and Adjustments. Perform the following initial checks before operating the instrument:

1. Allow a half-hour warm-up.
2. Depress the METER C/D push button (C position).
3. Depress the METER ON/OFF push button (ON position).
4. Set the D RANGE FS TEST push button to the out position.
5. Depress the D RANGE FS 0.1 push button.
6. Depress the C RANGE FS 100 pF push button.
7. Adjust the C ZERO control for a zero meter indication.
8. In sequence, depress each C RANGE FS push button and check for a zero meter indication.
9. Depress the C RANGE FS 10 nF push button.

10. Depress the TEST push button and check that the meter reads 10.0 ±0.05.
11. Set the METER C/D push button to the out (D) position and check that the meter reads 1.0 ±0.1.
12. Depress the D RANGE FS 0.01 push button and check that the meter reads 10.0 ±1.0.
13. Depress the C RANGE FS 100 nF push button and check that the meter reads 10.0 ±1.0 .
14. Depress the D RANGE FS OFF push button and check that the meter reads zero.
15. Depress the METER C/D push button (C position) and check that the meter reads 1.0 ±0.1.

3-2 MEASUREMENT CONSIDERATIONS

The Capacitance Meter measures the "direct" capacitance of a test specimen. (The instrument ignores shunt capacitance from the LO terminal to ground. Up to 1000 pF of shunt capacitance can be tolerated from the HI terminal to ground. As a result, the Capacitance Meter measures only the capacitance appearing between the HI and LO terminals.)

Measurements may be made locally at the TEST terminals or remotely by connecting the specimen or test fixture via coaxial cables to the TEST terminals. By use of both the TEST and STD terminals, differential capacitance measurements may be made within certain limitations.

3-3 MEASUREMENT CONNECTIONS

Although the TEST terminals are intended primarily for connecting coaxial cables, specimens may be connected directly to the terminals. A pair of Type UG-1090/U or equivalent BNC-to-binding-post adapters are particularly convenient for this purpose. For quick measurements, the leads of the specimen may be inserted directly into the center terminals of the BNC connectors.

3-4 PRELIMINARY CHECKS AND ADJUSTMENTS

Before making measurements, adjust the C ZERO control as follows:

a. Connect any adapters, cables, or test jig to be used during the measurement.

b. Depress the C RANGE FS 100 pF push button.

c. Adjust the C ZERO control for a zero indication on the meter.

NOTE:

Check that the D RANGE FS TEST push button is at the out position, because the in position will parallel a 10 nF capacitance across the test specimen during the measurement.

3-5 CAPACITANCE MEASUREMENT

Select the appropriate capacitance and dissipation range and connect the test specimen. Depress the METER C/D push button and read the capacitance value on the meter. Release the METER C/D push button and read the dissipation value on the meter.

3-6 DIFFERENTIAL CAPACITANCE MEASUREMENT

Measurement of the capacitance differential between two specimens may be made by connecting the larger value to the TEST terminals and the smaller value to the STD terminals. The meter will indicate the differential directly.

3-7 DIFFERENTIAL MEASUREMENT ACCURACY

The accuracy of differential measurements is affected by the voltage ratio of the TEST LO and STD LO terminals. This causes the effective capacitance across the STD terminals to be changed by the same factor. The voltage ratio is determined by a transformer and, therefore, is constant. If this ratio is accurately measured for any particular instrument, it may be applied as a correction factor for the capacitance across the STD terminals. The Capacitance Meter will read directly the difference between the "corrected" standard capacitor and the unknown capacitor.

Subject to the above correction, the instrument will read the capacitance differential within rated instrument accuracy. It should be noted, however, that as the differential

capacitance value becomes smaller, the measured dissipation tends to increase, since the loss factors may not balance as well as the capacitance. For capacitors of moderate Q and better (Q > 50) with a reasonable match in loss characteristics, it is possible to make differential measurements one or two ranges below the range used for direct measurement. Capacitors with very low dissipation may be measurable three ranges down.

3-8 DISSIPATION MEASUREMENT IN DIFFERENTIAL MODE

Normally, the direct mode is used to measure dissipation (Par. 3-5), because differential dissipation is not read directly on the meter. If required, the differential dissipation may be calculated by using the following equation:

$$Dx = \frac{\Delta C Di + Ds Cs}{Cs}$$

Where

ΔC = measured differential capacitance
Cx = test capacitor
Cs = standard capacitor
Di = indicated dissipation
Ds = dissipation of standard capacitor

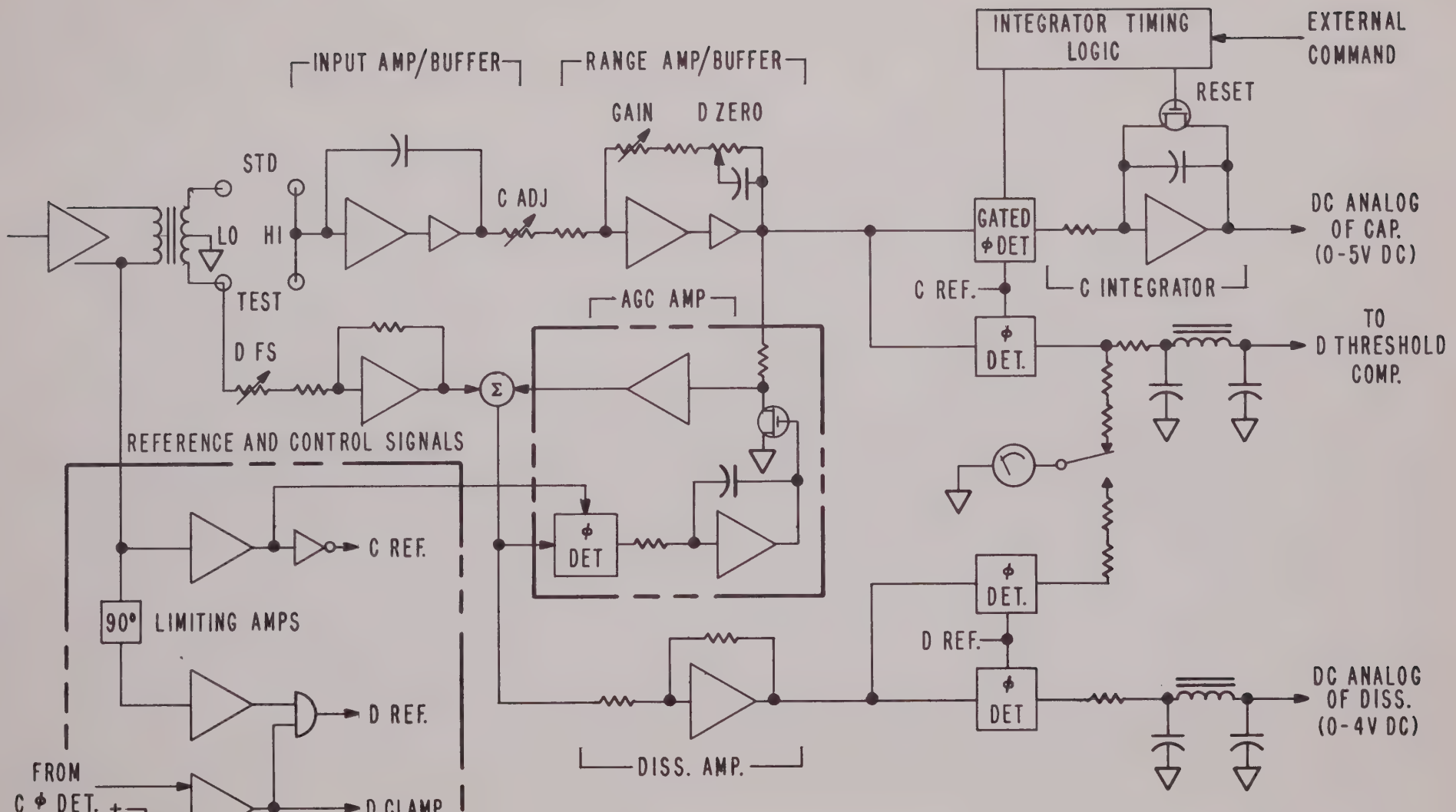


Figure 4-1. Functional Block Diagram

SECTION IV

THEORY OF OPERATION

4-1 BLOCK DIAGRAM ANALYSIS (Fig. 4-1)

a. Test-Level Control Circuits. The test signal in the 71K is generated by a 1 kHz Colpitts oscillator whose collector voltage is controlled by a series regulator. The output of the oscillator normally is about 8V p-p, with a collector voltage of about -10V. The buffer amplifier isolates the oscillator from loading by the test impedance. The gain from input to each collector of the push-pull amplifier is approximately 2X, for a signal of 16V p-p. The output transformer steps this down to 1V rms at the TEST LO and STD LO terminals.

The signal at the TEST LO terminal is applied to the primary of T102, which steps up the voltage to a full-wave diode rectifier. The rectifier output is compared with the internally generated 10V dc reference voltage by the oscillator control amplifier. Any error in the amplitude is amplified, and causes the oscillator series regulator to adjust the collector voltage in the direction required to minimize the amplitude error. The 10V dc reference voltage is derived from a low TC zener diode controlled voltage regulator.

b. Measurement Functions. The input amplifier and buffer function as an operational amplifier whose external elements are the capacitor under test and a stable feedback capacitor. The amount of feedback is such that the output level is linearly related to the value of the test capacitor. Additionally, the dissipation of the test capacitor causes a phase shift of the output signal. The signal from the input amplifier/buffer drives the range amplifier/buffer. This stage provides gain and phase trimming for each capacitance range. The output level is about 2.2V rms. The analog signal branches at this point to the capacitance and dissipation channels, which essentially function in parallel and provide simultaneous voltage analogs of the capacitance and dissipation.

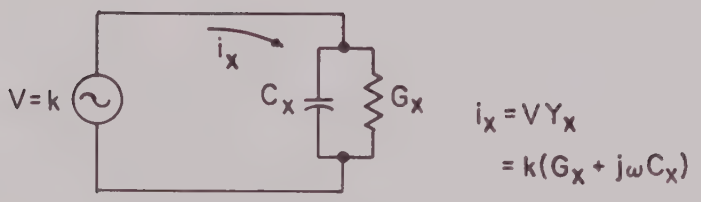
The capacitance channel is divided into two main sections. The first section is a phase detector (or driven switch) which converts the ac analog of capacitance into a dc analog. The phase detector provides a linear output and rejects the effects of the dissipation on the measurement. This output is used to drive the panel meter and the dissipation threshold comparator. The second section of the capacitance channel is the switched integrator which provides the dc analog for external limit comparisons. This part comprises a gated phase detector, an active integrator and reset switch, and the necessary logic and control circuitry. This portion of the capacitance channel functions only upon receipt of an external command signal. At that time it samples the ac analog signal for a fixed number of cycles and then holds the resultant dc long enough for a limit comparison.

The dissipation channel processes the ac analog signal from the range amplifier to extract the dissipation (loss) signal. This signal normally is much smaller than the capacitance information carried by this signal. The function of the agc amplifier in the dissipation channel is to amplify the ac analog to a fixed level, so that the capacitance phase may be subtracted. This process also effectively divides the loss signal by the capacitance and yields an output which is proportional to the dissipation of the test capacitor, the desired indication. The resultant dissipation signal, which is at quadrature phase, now may be further amplified before being applied to the phase detectors. The gain of the dissipation range amplifier is changed by a factor of 10 between the two dissipation ranges.

Parallel phase detectors provide outputs to the panel meter and to a low-pass filter for the dc analog voltage for external limit comparisons for dissipation. There are several control signals in the 71K. The drive signals for the phase detectors are obtained from limiting amplifiers driven from the primary of the output transformer. The dissipation clamp signal disables various sections of the dissipation channel in the absence of a usable signal.

4-2 MEASUREMENT PRINCIPLES

The basis of measurement in the Capacitance Meter is shown in Figure 4-2A. A capacitor is driven by a 1-kHz voltage source, and the current through the capacitor is proportional to capacitance and shunt conductance. However, in order to make use of the above relationship, the current flowing in the test capacitor must be converted to a proportional voltage. Furthermore, the current must be sampled in a manner that does not introduce additional impedance in the test circuit. In essence, we require a zero input impedance current-to-voltage converter, as shown in Figure 4-2B.



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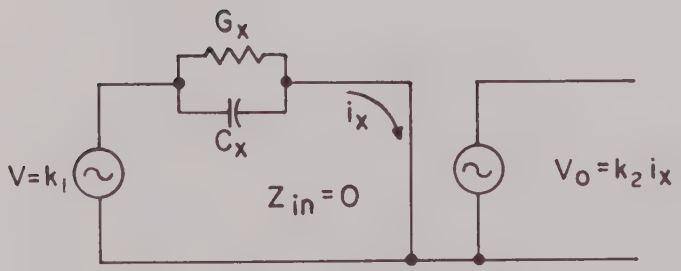


B

Figure 4-2

These requirements are met by using a high-gain operational amplifier connected in the inverting mode (Figure 4-3).

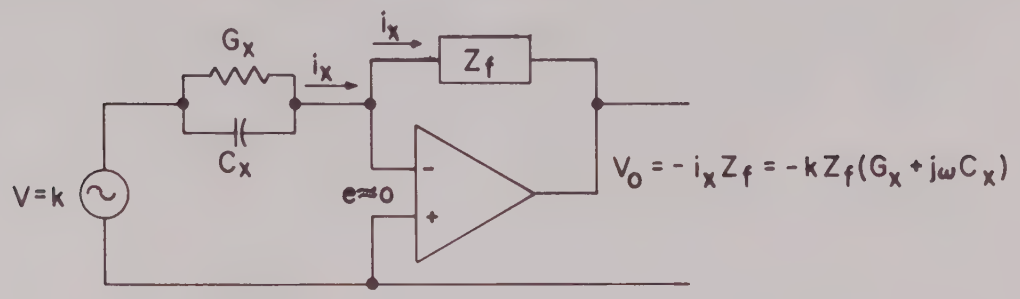


Figure 4-3

As shown in Figure 4-4, capacitor C_f is the major signal feedback element in the Capacitance Meter. This accomplishes two things: The in-phase component of the output voltage is proportional to the unknown capacitance, and the measured capacitance value is insensitive to frequency variation.

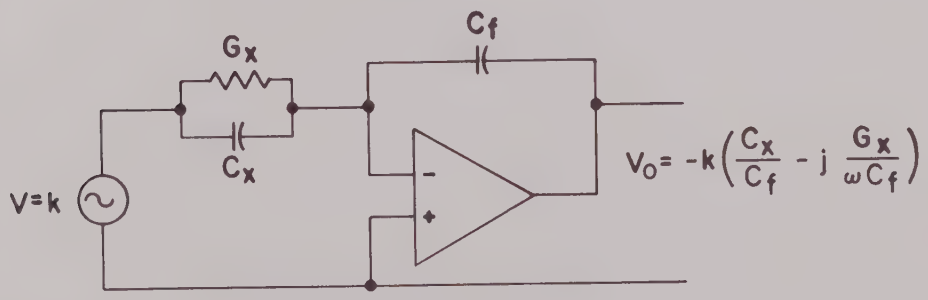


Figure 4-4

The output of the current-to-voltage converter is a voltage analog of the test capacitor. The magnitude of the in-phase component is proportional to capacitance, while the magnitude of the quadrature phase is proportional to conductance. This analog signal is processed by the Capacitance Meter in order to separate these two components and develop dc analog voltages proportional to the capacitance and dissipation of the test specimen (Figure 4-5). The circuitry required to implement these functions will be described in the following paragraphs.

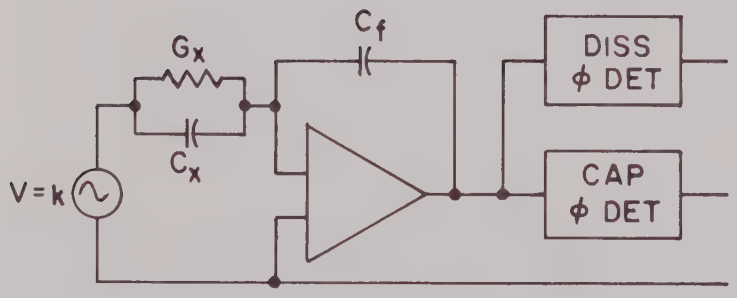


Figure 4-5

a. 1-kHz Voltage Source. The test voltage applied to the test capacitor is continuously compared with a stable dc voltage, and any error in the test voltage is amplified and applied to control circuitry so that the level adjusts to the proper value. A simplified diagram is shown in Figure 4-6.

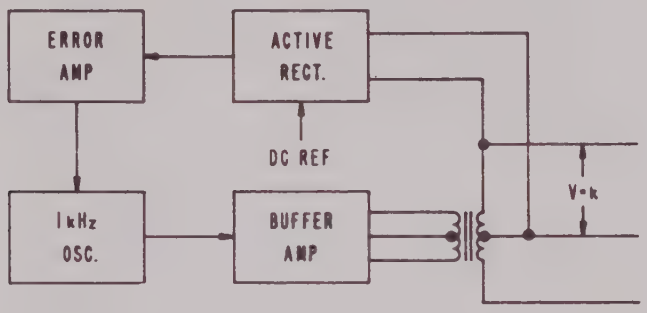


Figure 4-6

The signal voltage applied to the test capacitor also is fed to an active rectifier which converts the ac signal to a proportional dc signal which is summed with the dc reference voltage, and the error amplifier develops the oscillator control voltage with an active integrator. This control voltage varies the collector voltage of the 1 kHz oscillator, and hence adjusts the signal amplitude. The buffer amplifier isolates the oscillator from load variations. A more complete schematic is shown in Figure 4-7.

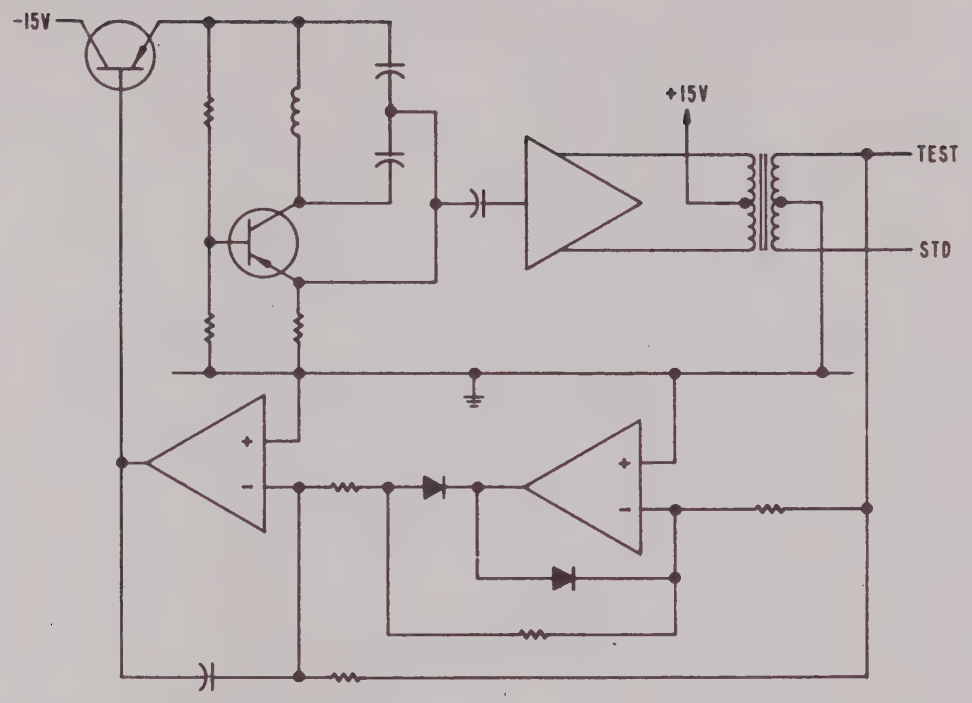


Figure 4-7

An out-of-phase voltage is available at the STD terminal. This voltage is required to zero out any stray capacitance, and it may be used to make differential capacitance measurements.

b. Capacitance-to-Voltage Converter. The input amplifier described in Paragraph 4-2 is used to convert capacitance to analog voltage. This stage is followed by an inverting amplifier which provides gain and phase trimming for each capacitance range (Figure 4-8).

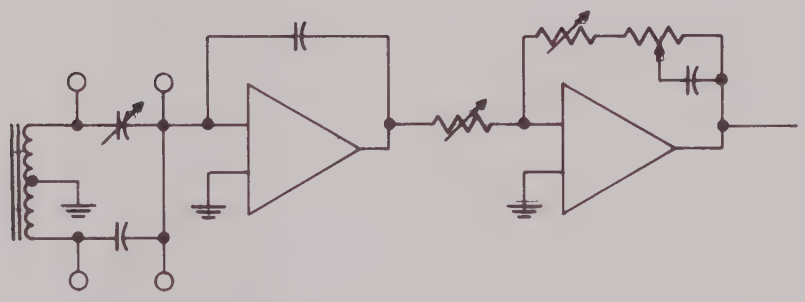


Figure 4-8

The input amplifier uses a single feedback capacitor for two decade ranges and minimizes the number of standard capacitors required. However, the second amplifier-stage gain must change by a factor of 10 on alternate ranges. This is accomplished by changing the input resistor to the second amplifier by a factor of 10 on alternate ranges.

Thus far, the discussion of the input amplifier has ignored dc operating point stability. Obviously, some method of introducing dc feedback from the output to the input is required if the amplifier is to achieve a stable dc operating point

This is accomplished by placing a network in parallel with each feedback capacitor (Figure 4-9). The network is designed for a very small in-phase feedback signal at 1 kHz, while providing dc stability.

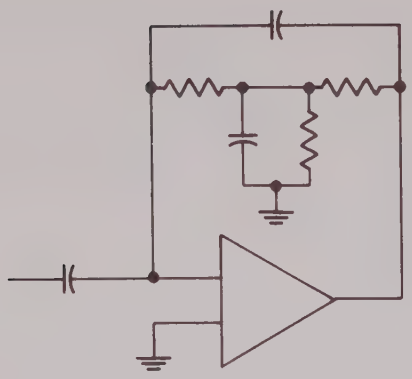


Figure 4-9

Another consideration involves the feedback impedance when large capacitors are measured. In this case, the basic amplifier is unable to supply sufficient current, so a unity gain buffer is added (Figure 4-10).

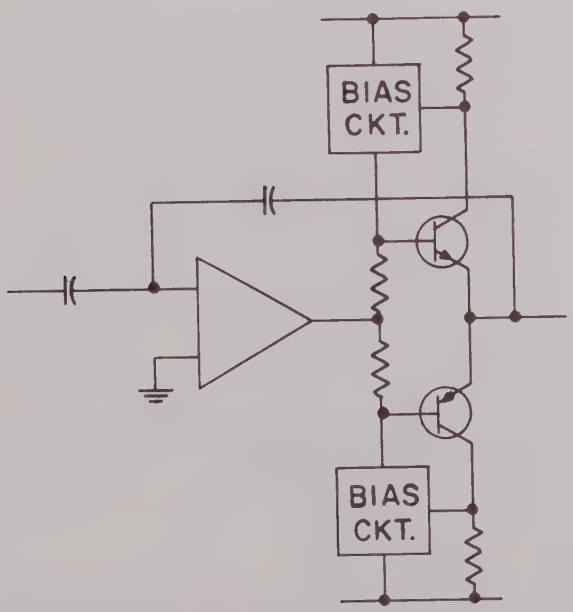


Figure 4-10

A similar situation occurs at the output of the second amplifier, and a unity gain buffer is added (Figure 4-11). However, this buffer is of simpler design, since the requirements are less stringent. Voltage limiting is applied to this stage to avoid overdriving the phase detectors which follow.

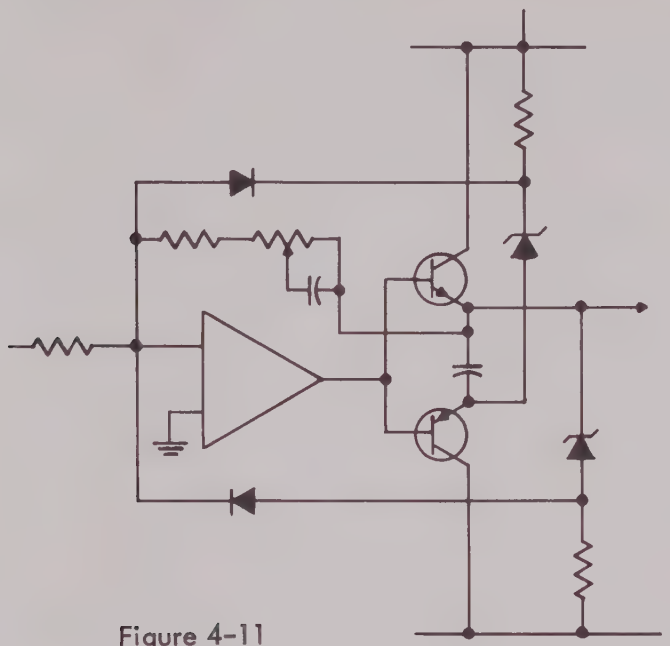


Figure 4-11

c. Capacitance Phase Detector. The signal from the capacitance-to-analog voltage converter is fed to a pair of analog switches (Figure 4-12) which function as parallel, phase-sensitive detectors. The switches are driven by a square wave derived from the test signal. The positive output is fed directly to the panel meter, while the negative output drives a switched active integrator for external limit comparisons.

The field-effect transistors used as analog switches provide an excellent on off ratio and have no inherent offset voltage.

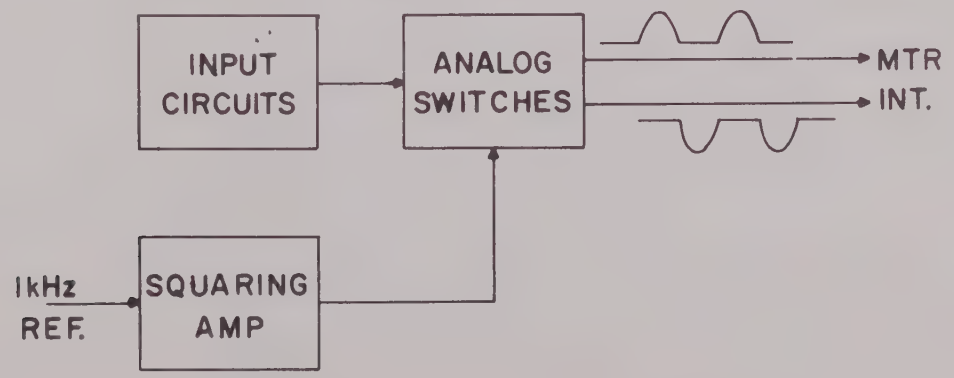


Figure 4-12

71K
a

d. Capacitance Integrator. The active integrator that develops the external limit-comparison voltage provides a relatively rapid rise time with a ripple-free output voltage during limit comparisons.

An external command signal is required (Figure 4-13). This signal should range from <-0.5 V to >-5.0 V when a limit comparison is to be made, and it must remain at the high level for the duration of the test. The command signal must reset to the low level for at least 10 ms between tests.

The integrator normally is reset to zero. The command signal releases the reset and enables a synchronous one-shot which allows 16 negative cycles to pass the phase detector. The voltage then is integrated, and the final output voltage is held until the termination of the test. When the command signal goes low, the integrator is reset, and the system is ready for another test cycle.

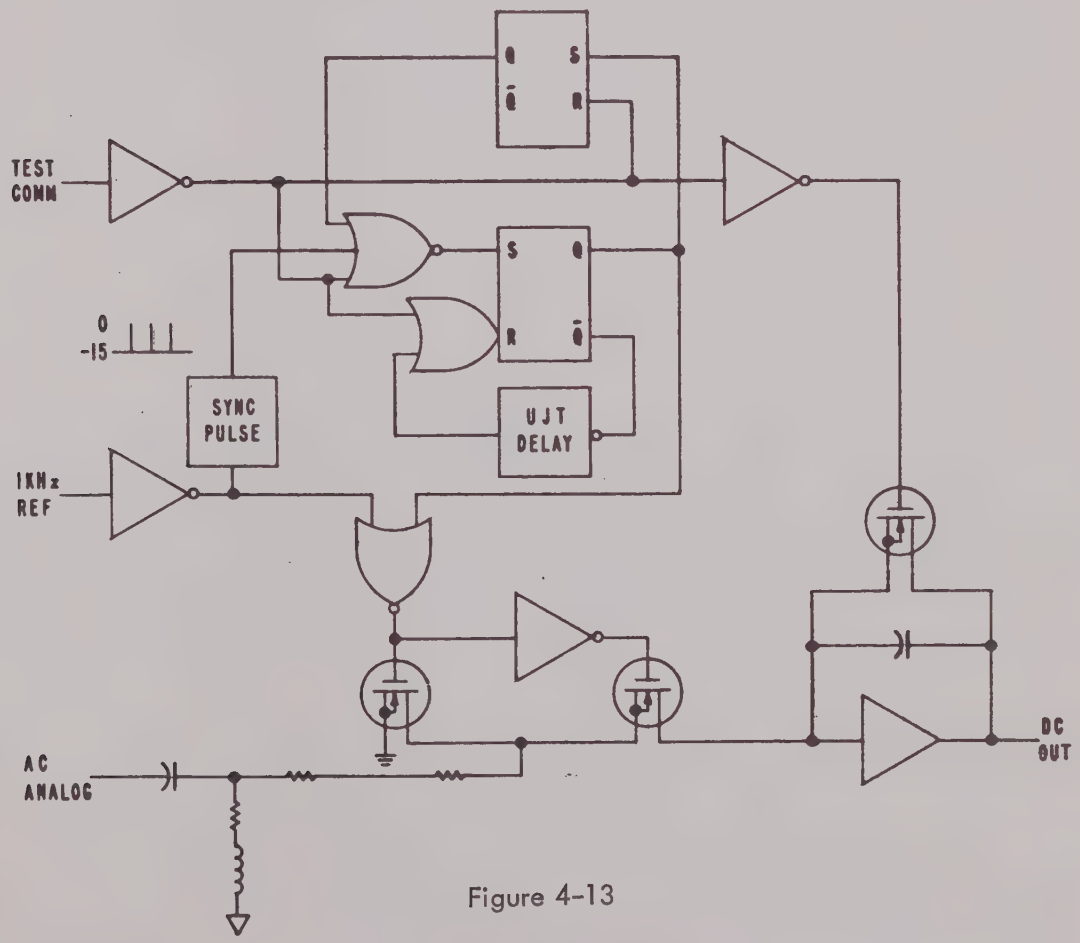


Figure 4-13

e. Dissipation Circuits. The quadrature component of the analog signal is proportional to the conductance of the test specimen. A more desirable indication of this quantity is the dissipation of the test capacitor, where $D_x = G_x/\omega C$.

This transformation is accomplished by normalizing the in-phase component and then subtracting it from the normalized signal. The resulting small quadrature signal, which is proportional to D_x, may be amplified further and converted to dc by means of a phase detector operating in quadrature phase. A simplified diagram is shown in Figure 4-14.

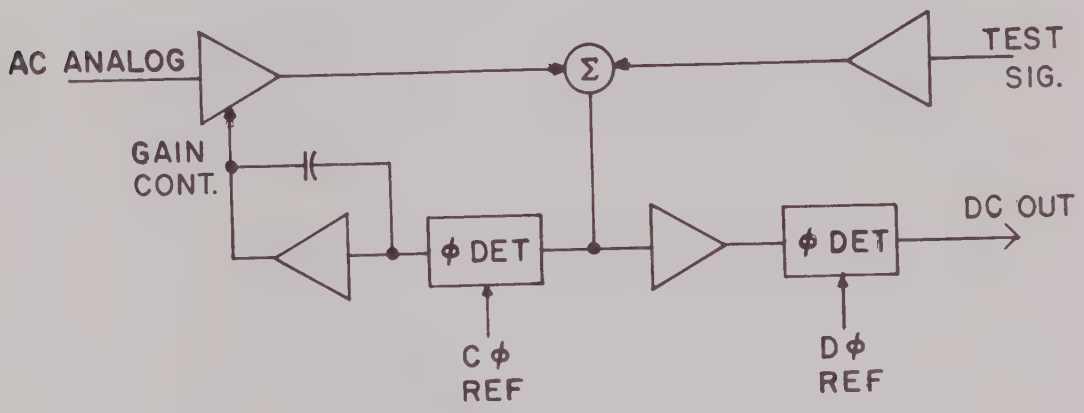


Figure 4-14

The actual circuit implementation contains auxiliary circuitry which does not affect the basic function. Balance speed is improved by a "two-speed" switch in the agc integrator which allows fast balance and low distortion for accurate measurement. Response time is improved by applying a clamping signal to the integrator so that the agc amplifier is held at low gain in the absence of an input signal.

SECTION V

MAINTENANCE

5-1 GENERAL

a. It is beyond the scope of this instruction manual to provide detailed maintenance procedures with troubleshooting charts that cover every possible fault that could occur in the Capacitance Meter. However, this section contains complete calibration procedures and enough troubleshooting information to permit an experienced technician to localize a fault to an assembly, such as a printed circuit card. Once the fault is localized, conventional measurement and test techniques can be used to isolate the defective part. Furthermore, engineering personnel of the Boonton Electronics Corporation are available for consultation and assistance if maintenance problems arise.

b. An understanding of the Capacitance Meter's functional operation and signal flow will facilitate troubleshooting. It is recommended that the theory section be carefully reviewed. Also refer to Figures 5-1 through 5-12, at the rear of this section, for schematic and parts location information. The values of component parts are indicated in the schematic diagrams and in the parts list at the rear of this manual.

5-2 CORRECTIVE MAINTENANCE

a. General. The first step in troubleshooting a fault is to determine whether the entire equipment is inoperative or if only a partial failure exists. This is readily accomplished by checking the performance of the Capacitance Meter on each capacitance and dissipation range. The results of this checkout will provide valuable diagnostic information because some circuits are common to all measurement functions while others are common either to capacitance measurement functions or to dissipation measurement functions. If the entire instrument is dead, refer to paragraph b. When a fault is limited to capacitance measurements, refer to paragraph c. For faults appearing only in dissipation measurements, refer to paragraph d.

b. Total Failure of Capacitance Meter. Check the following:

1. Power supply output voltages.
2. 10V reference voltage.

3. 1 kHz test signal.
4. 1st Signal-Amplifier/Buffer output.
5. 2nd Signal-Amplifier/Buffer output.
6. C Phase Detector/Phase-Dectector Driver.
7. Meter and meter switch.

c. Faults in Capacitance Measurement Circuits. Check the following:

1. Power supplies.
2. 10V Reference.
3. Oscillator-Driver and Control Amplifier.
4. 1st Signal-Amplifier/Buffer.
5. 2nd Signal-Amplifier/Buffer.
6. C Phase Detector/Phase-Detector Driver.
7. Meter
8. Switches and all associated wiring.

d. Faults in Dissipation Measurement Circuits. Check the following:

1. D Detector Circuits.
2. D Phase-Detector Driver.
3. D Threshold Detector.
4. Switches and all associated wiring.
5. Meter (if also inoperative during C checkout).

5-3 CALIBRATION

a. General.

The Capacitance Meter normally is calibrated at 30-day intervals, but this period will be ultimately determined by the calibration history of the instrument. The calibration controls are accessible under the cover plate on the front panel (Figure 2-1). Remove the cover plate by pulling the two black plungers outward. Reinstall the cover plate (Par. 2-4a(11)) when calibration is completed.

b. Test Accessories Required.

1. One set of capacitance standards, or equivalent. The value of the capacitors should approximate, but not exceed, the full-scale values indicated at the C RANGE FS push buttons. Each capacitor should have a dissipation figure as small as practicable, preferably < 0.001.

2. One capacitance standard, or equivalent, with a dissipation figure < 0.01. The value of the capacitor should approximate, but not exceed, 10 nF.

3. One small screwdriver or alignment tool.

c. Meter-Zero Calibration.

1. Release the METER ON/OFF push button (METER OFF).

2. Check that the front-panel meter pointer rests exactly at 0. If necessary, rotate the screwdriver-adjust control, directly below the meter, for a zero indication.

d. C ZERO Calibration.

1. Depress the C RANGE FS 100 pF push button.

2. Release the D RANGE FS TEST push button (off position).

3. Depress the METER C/D push button (C position).

4. Depress the METER ON/OFF push button (METER ON).

5. Check that the meter pointer rests exactly at 0. If necessary, adjust the C ZERO control for a zero indication.

e. D RANGE FS Calibration.

1. Connect the(nominal) 10 nF (D = <0.001) capacitance standard to the TEST HI and LO front-panel terminals.

2. Depress the C RANGE FS 10 nF push button.

3. Depress the D RANGE FS 0.01 push button.

4. Release the METER C/D push button (D position).

5. Check that the dissipation reading on the front-panel meter concurs with the D figure of the standard. If necessary, adjust the D ZERO 10 nF control until the two D values coincide.

6. Remove the standard from the TEST terminals and install the (nominal)10 nF (D =< 0.01) capacitance standard.

7. Check that the dissipation reading on the front-panel meter concurs with the D figure of the standard. If necessary, adjust the D FS control until the two D values coincide.

8. Remove the standard from the TEST terminals.

f. C RANGE FS and D RANGE FS Calibration.

1. Check that the D RANGE FS TEST push button is at the out position.

2. Depress the D RANGE FS OFF push button.

3. Depress the METER C/D push button (C position).

4. Depress the C RANGE FS 10 nF push button.

5. Connect the (nominal) 10 nF capacitance standard (D =< 0.001) to the TEST HI and LO terminals.

6. Read the front-panel meter. The meter reading should agree with the C value of the capacitance standard. If necessary, adjust the C ADJ 10 nF control until the meter indicates the exact C value of the capacitance standard.

7. Remove the (nominal) 10 nF capacitance standard.

8. Depress the 100 pF C RANGE FS push button.

9. Connect the (nominal) 100 pF capacitance standard to the TEST HI and LO terminals.

10. Read the front-panel meter. The meter reading should agree with the C value of the capacitance standard. If necessary, adjust the C ADJ 100 pF control until the meter indicates the exact C value of the capacitance standard.

11. Depress the D RANGE FS 0.01 push button.

12. Release the METER C/D push button (D position).

13. Read the front-panel meter. The meter reading should agree with the D figure of the capacitance standard. If necessary, adjust the D ZERO 100 pF control until the meter indicates the exact D value of the capacitance standard.

14. Depress the D RANGE FS ON/OFF push button.

15. Remove the (nominal) 100 pF capacitance standard.

16. Sequentially connect each remaining capacitance standard and repeat steps 8 through 15, except use the push button or control that corresponds with the value of the capacitance standard in steps 8, 10, and 13.

g. Periodic Calibration Checks. The D RANGE FS TEST capacitor may be used to perform quick calibration checks of the Capacitance Meter. First establish and record C and D reference values for the test capacitor by performing the procedure below as soon as calibration is completed (Par. b through f, above). Then perform the following procedure periodically, as required, and compare the C and D reading (steps 6 and 8) with the reference values. The Capacitance Meter should be recalibrated if a deviation between a checkout reading and a reference value exceeds either the tolerance specified in Section I or the user's specification, as applicable.

1. Depress the C RANGE FS 10 nF push button.

2. Depress the D RANGE FS 0.01 push button.

3. Depress the D RANGE FS TEST push button.

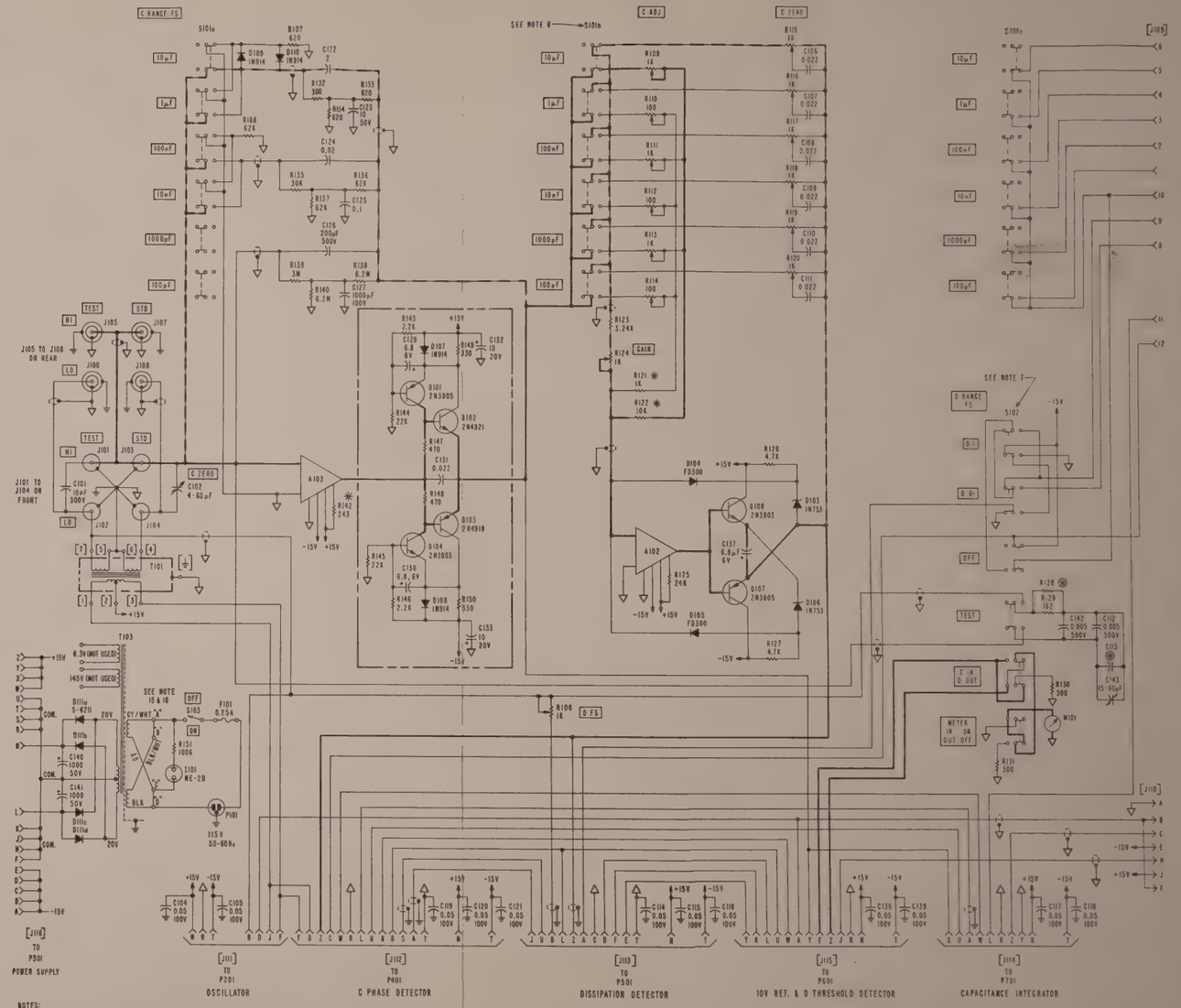
4. Depress the METER C/D push button

5. Depress the METER ON/OFF push button.

6. Note the C reading of the test capacitor.

7. Release the METER C/D push button.

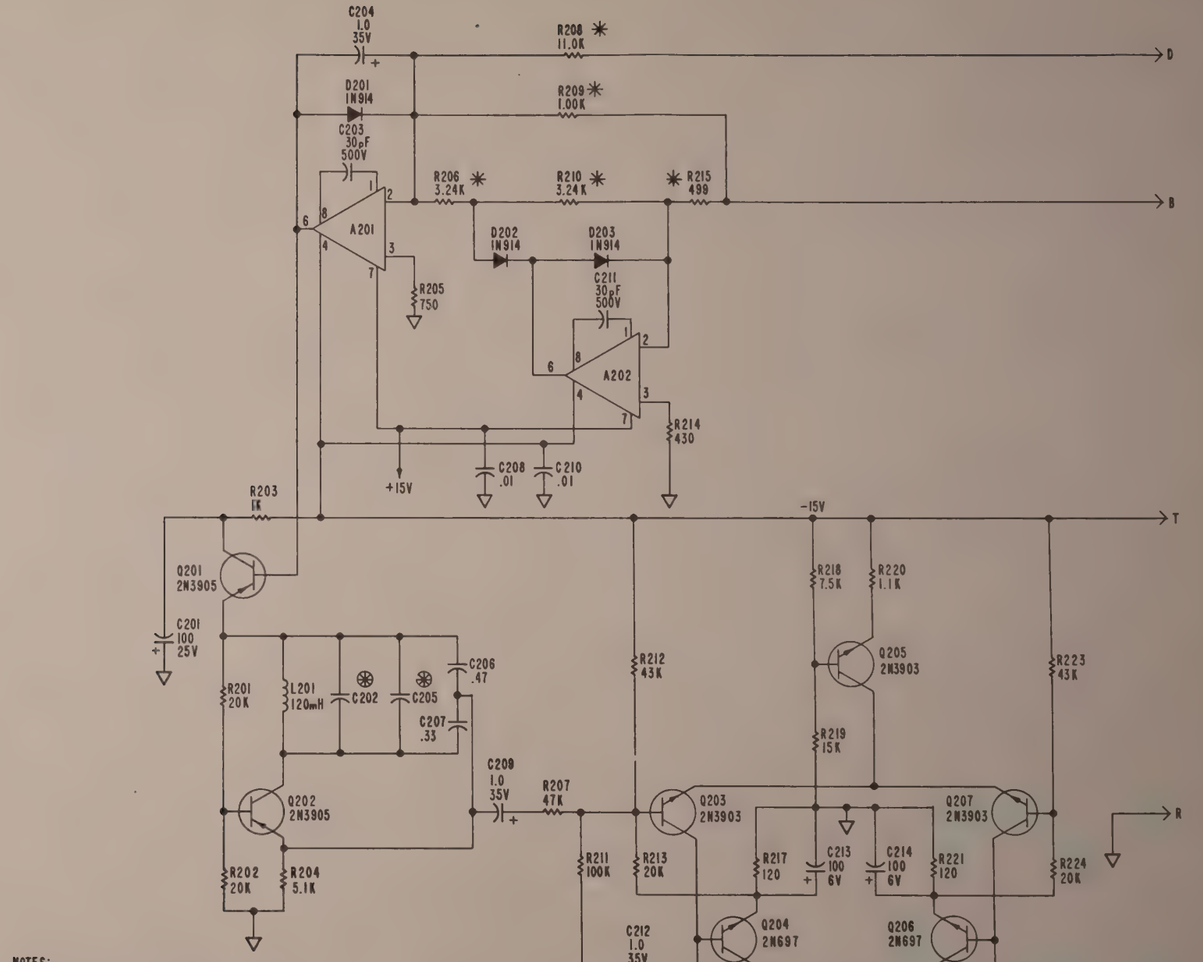
8. Note the D reading of the test capacitor.



NOTES:

1. VOLTAGE RATING OF CAPACITORS IS 200V, UNLESS OTHERWISE SPECIFIED.
2. CAPACITANCE IN μF, UNLESS OTHERWISE SPECIFIED.
3. RESISTANCE VALUES IN OHMS AND 1/2 WATT, UNLESS OTHERWISE SPECIFIED.
4. ✳ PRECISION RESISTORS.
5. ⊛ FACTORY SELECTED.
6. SWITCH S101 SHOWN IN 10μF "ON" POSITION.
7. SWITCH S102 POSITIONS:
   a. SWITCH SHOWN IN "D" OFF POSITION.
   b. SWITCH SHOWN IN "TEST" OFF POSITION.
   c. SWITCH SHOWN IN "C" POSITION "IN."
   d. SWITCH SHOWN IN "METER ON" POSITION "IN."
8. ——— SIGNAL PATH.
9. ——— FEEDBACK PATH.
10. ⏚ CHASSIS GROUND.
11. ▽ COMMON.
12. ▭ EXTERNAL MARKINGS.
13. [ ] INTERNAL MARKINGS
14. LAST NUMBERS USED:
    R151 C143
15. FOR 115V OPERATION, CONNECT "A" TO "B" AND "C" TO "D."
16. FOR 230V OPERATION, CONNECT "B" TO "C," AND REMOVE "A" TO "B" AND "C" TO "D."
17. NUMBERS NOT USED.
    R141 C128

Figure 5-1. Switching & Interconnection Diagram



NOTES:

VOLTAGE RATING OF CAPACITORS IS 200V UNLESS OTHERWISE SPECIFIED.

CAPACITANCE IN μF UNLESS OTHERWISE SPECIFIED.

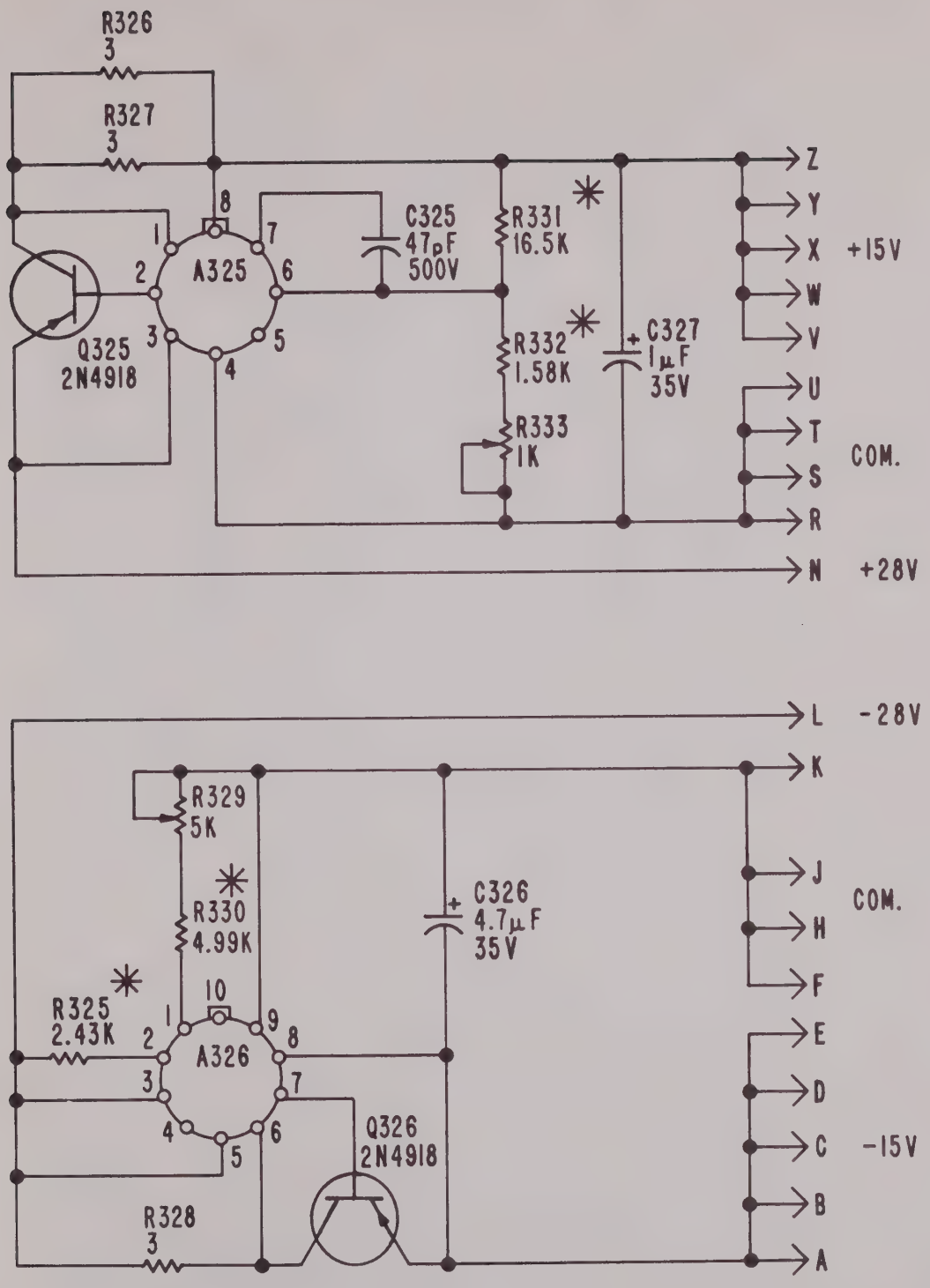
RESISTANCE VALUES IN OHMS AND 1/2 WATT UNLESS OTHERWISE SPECIFIED.

✳ PRECISION RESISTORS.

⊛ FACTORY SELECTED VALUE.

LAST NUMBER USED
R224 C214

Figure 5-2. Oscillator, Schematic Diagram.



NOTES:

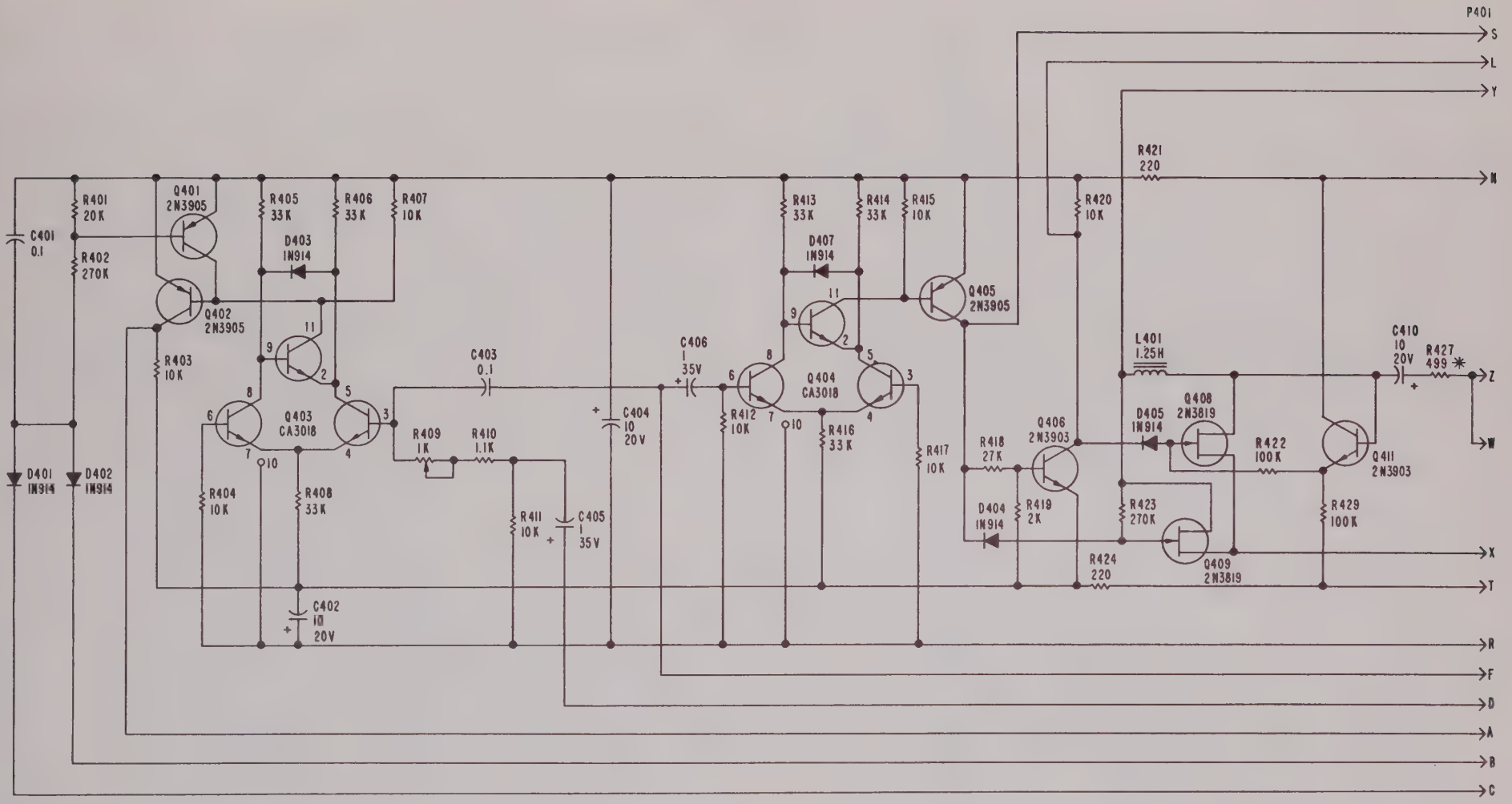
RESISTANCE VALUES IN OHMS & 1/2 WATT UNLESS OTHERWISE SPECIFIED.

✳ PRECISION RESISTORS

LAST NUMBER USED

R333 C327

Figure 5-3. Power Supply, Schematic Diagram.



NOTES:

VOLTAGE RATING OF CAPACITORS IS 200 V UNLESS OTHERWISE SPECIFIED.

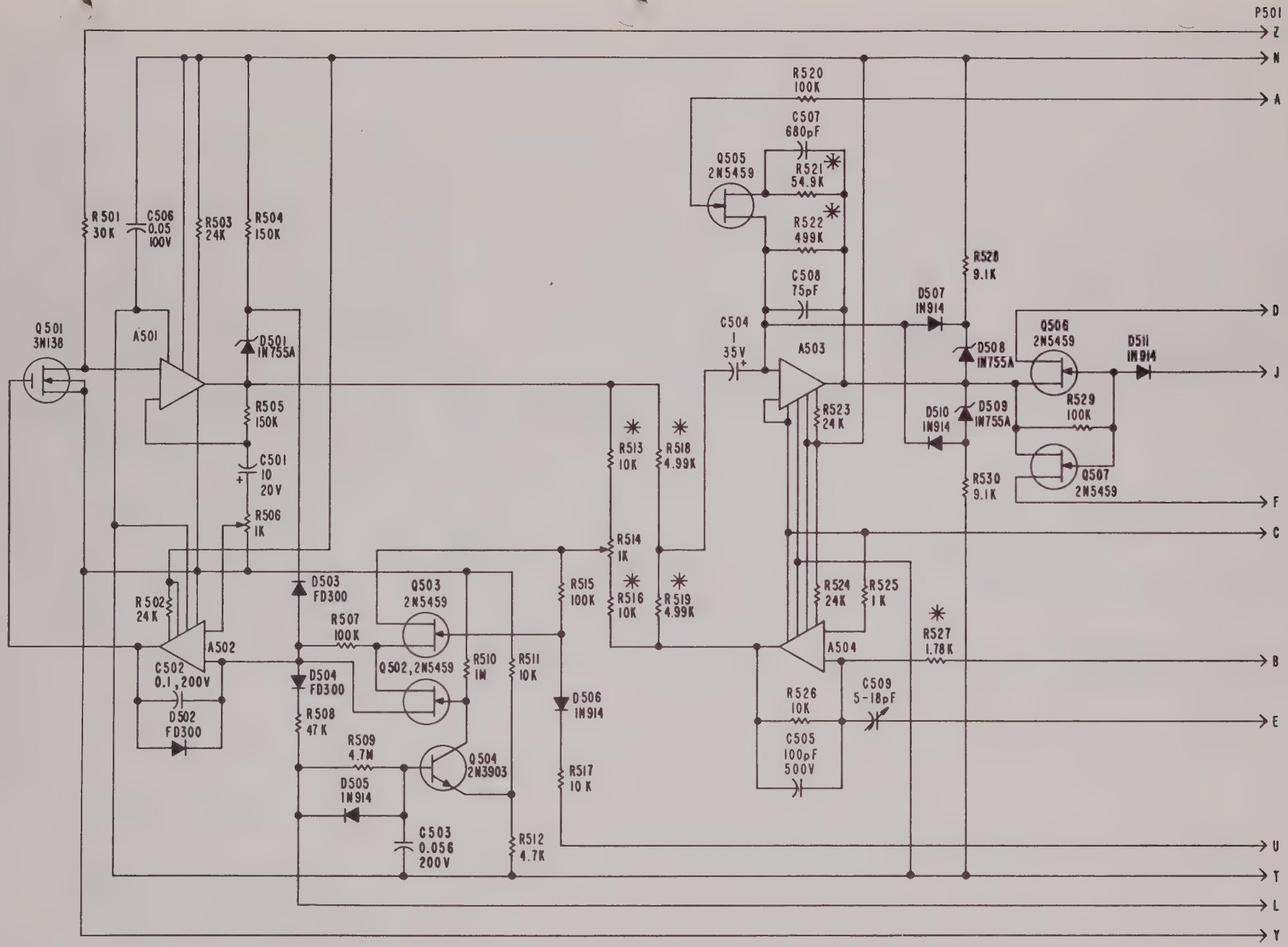
CAPACITANCE IN μF UNLESS OTHERWISE SPECIFIED.

RESISTANCE VALUES IN OHMS AND 1/2 WATT UNLESS OTHERWISE SPECIFIED.

* PRECISION RESISTORS.

LAST NUMBER USED R429 C410

Figure 5-4. C Phase Detector, Schematic Diagram.



NOTES:

CAPACITANCE IN μF UNLESS OTHERWISE SPECIFIED.
RESISTANCE VALUES IN OHMS AND 1/2 WATT UNLESS OTHERWISE SPECIFIED.
✳ PRECISION RESISTORS.

LAST NUMBERS USED:
R530 C509

Figure 5-5. Dissipation Detector, Schematic Diagram.

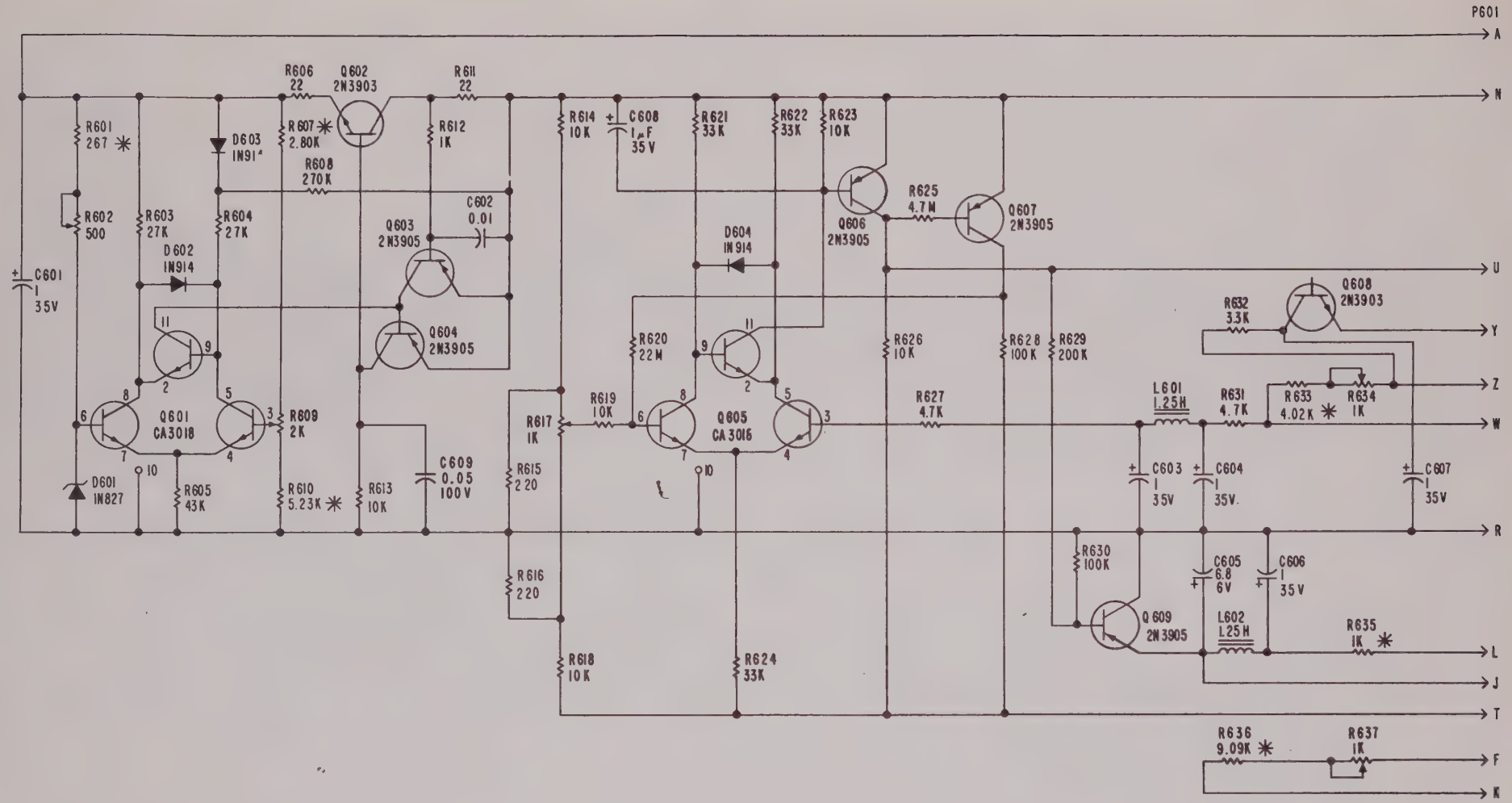


Figure 5-6. 10V Reference & D Threshold Detector, Schematic Diagram.

NOTES:

VOLTAGE RATING OF CAPACITORS IS 200V UNLESS OTHERWISE SPECIFIED.

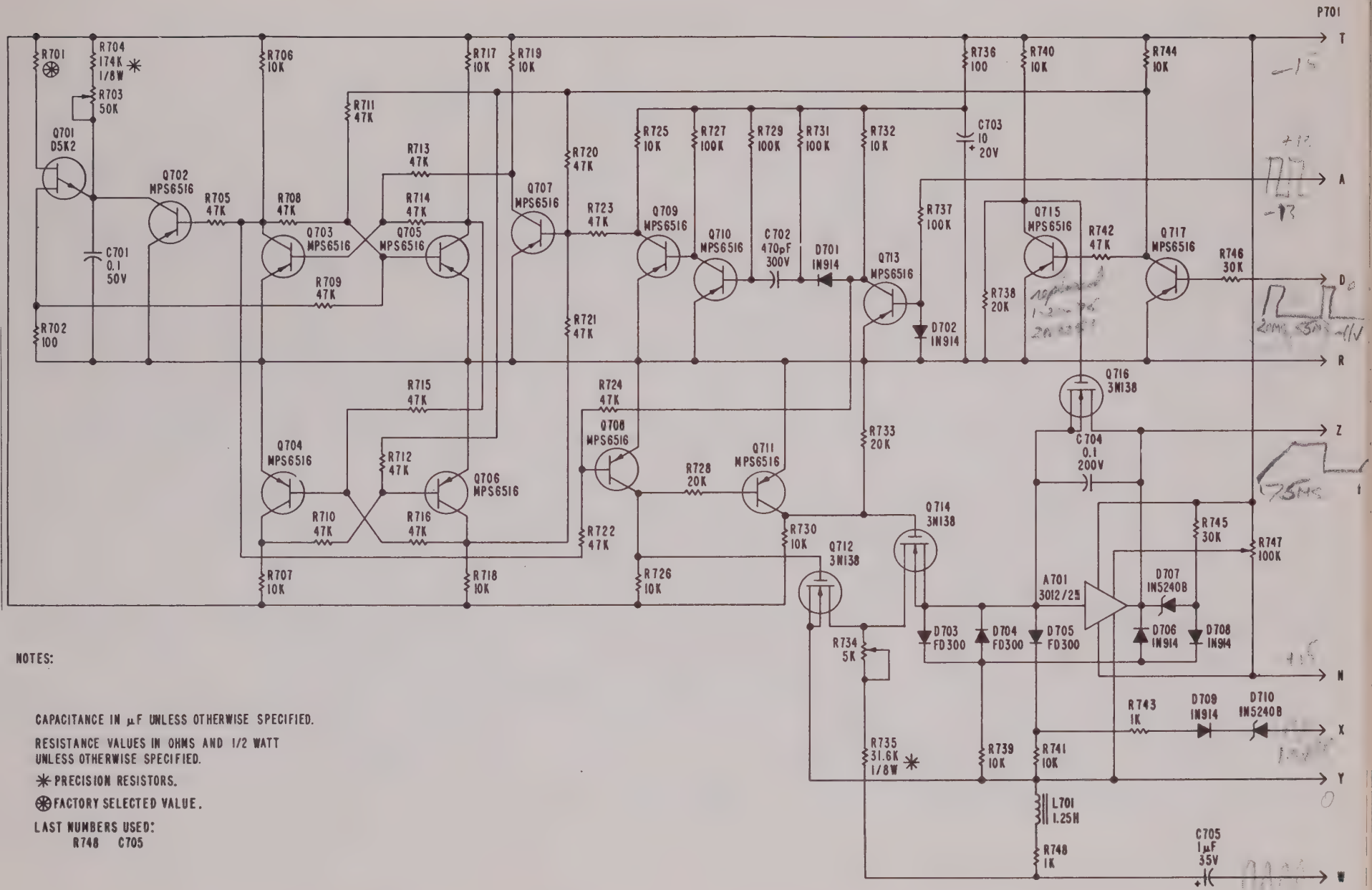
CAPACITANCE IN μF UNLESS OTHERWISE SPECIFIED.

RESISTANCE VALUES IN OHMS AND 1/2 WATT UNLESS OTHERWISE SPECIFIED.

✳ PRECISION RESISTORS.

LAST NUMBERS USED:

R637 C609



NOTES:

CAPACITANCE IN µF UNLESS OTHERWISE SPECIFIED.

RESISTANCE VALUES IN OHMS AND 1/2 WATT UNLESS OTHERWISE SPECIFIED.

✳ PRECISION RESISTORS.

⊛ FACTORY SELECTED VALUE.

LAST NUMBERS USED:
R748 C705

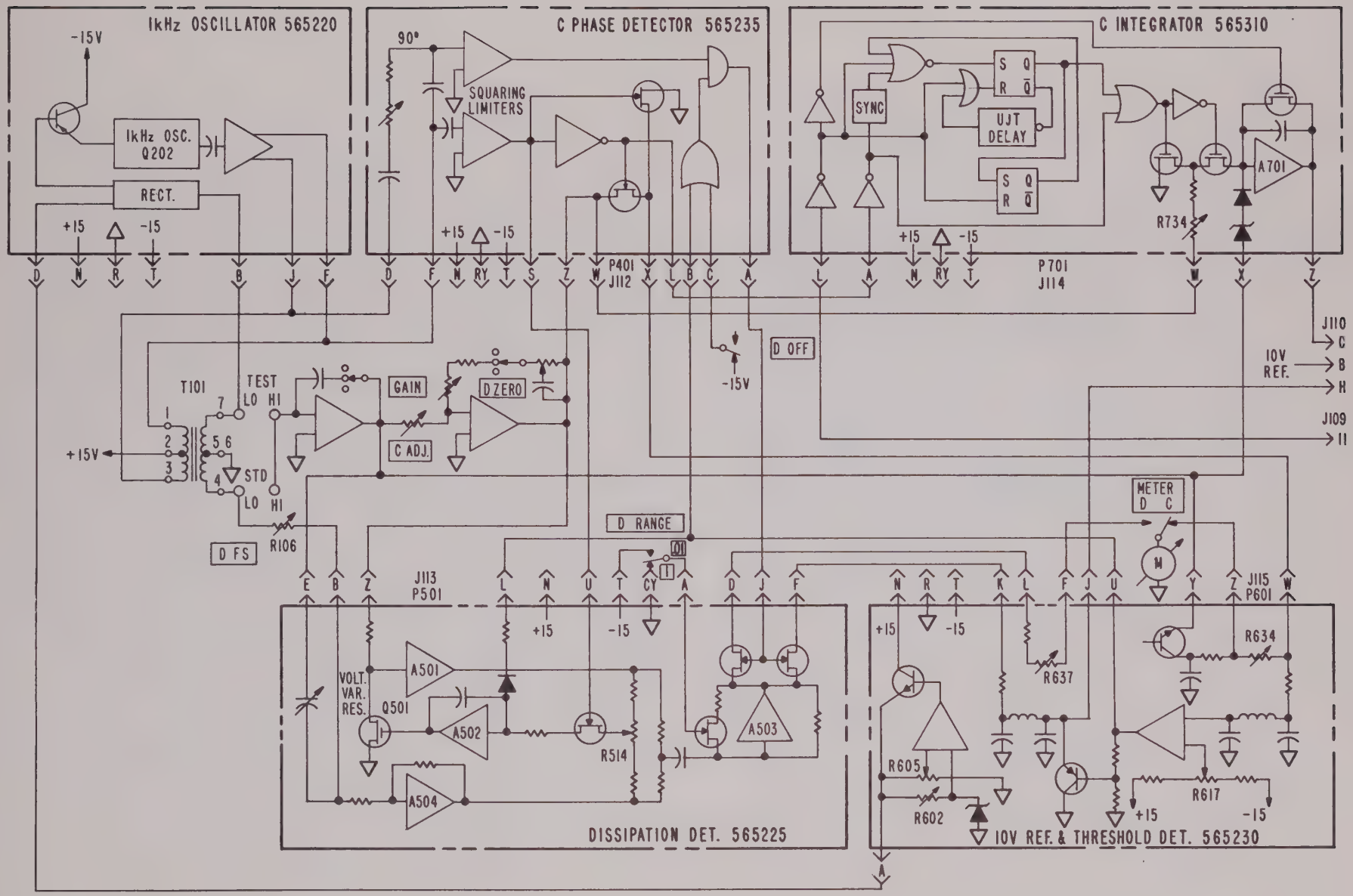


Figure 5-8. Printed Circuit Board Interconnection Diagram.

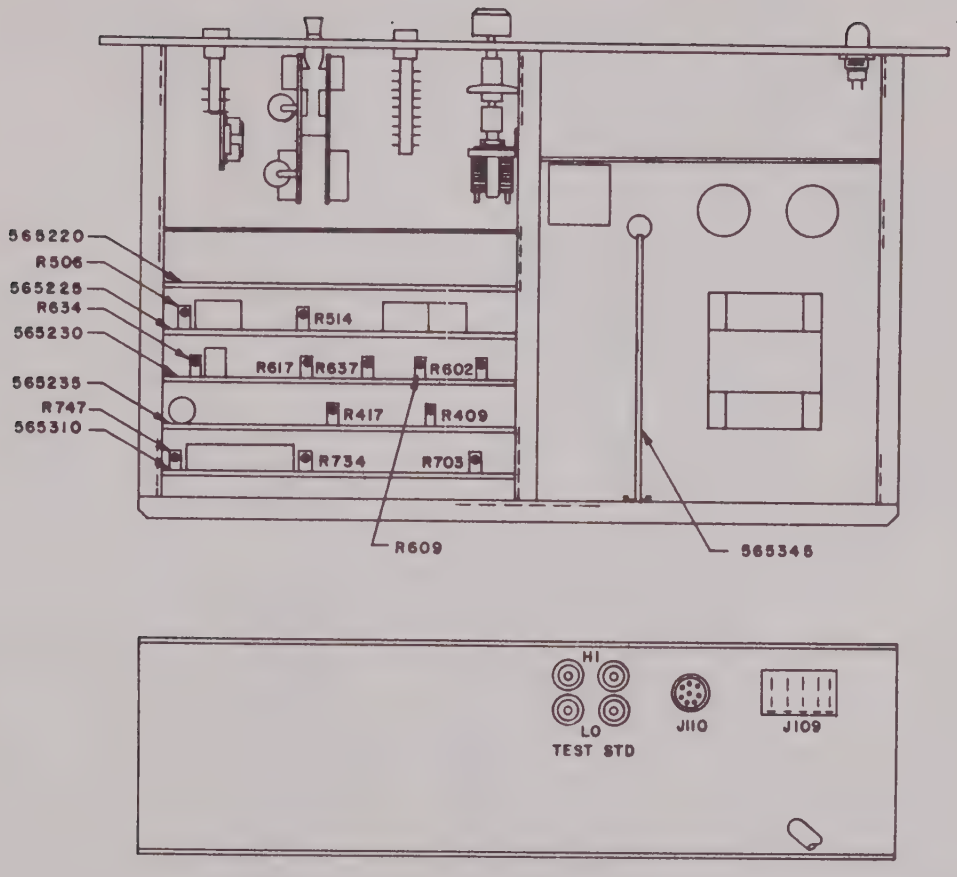


Figure 5-9. Locations of PC Boards, Controls, & Connectors.

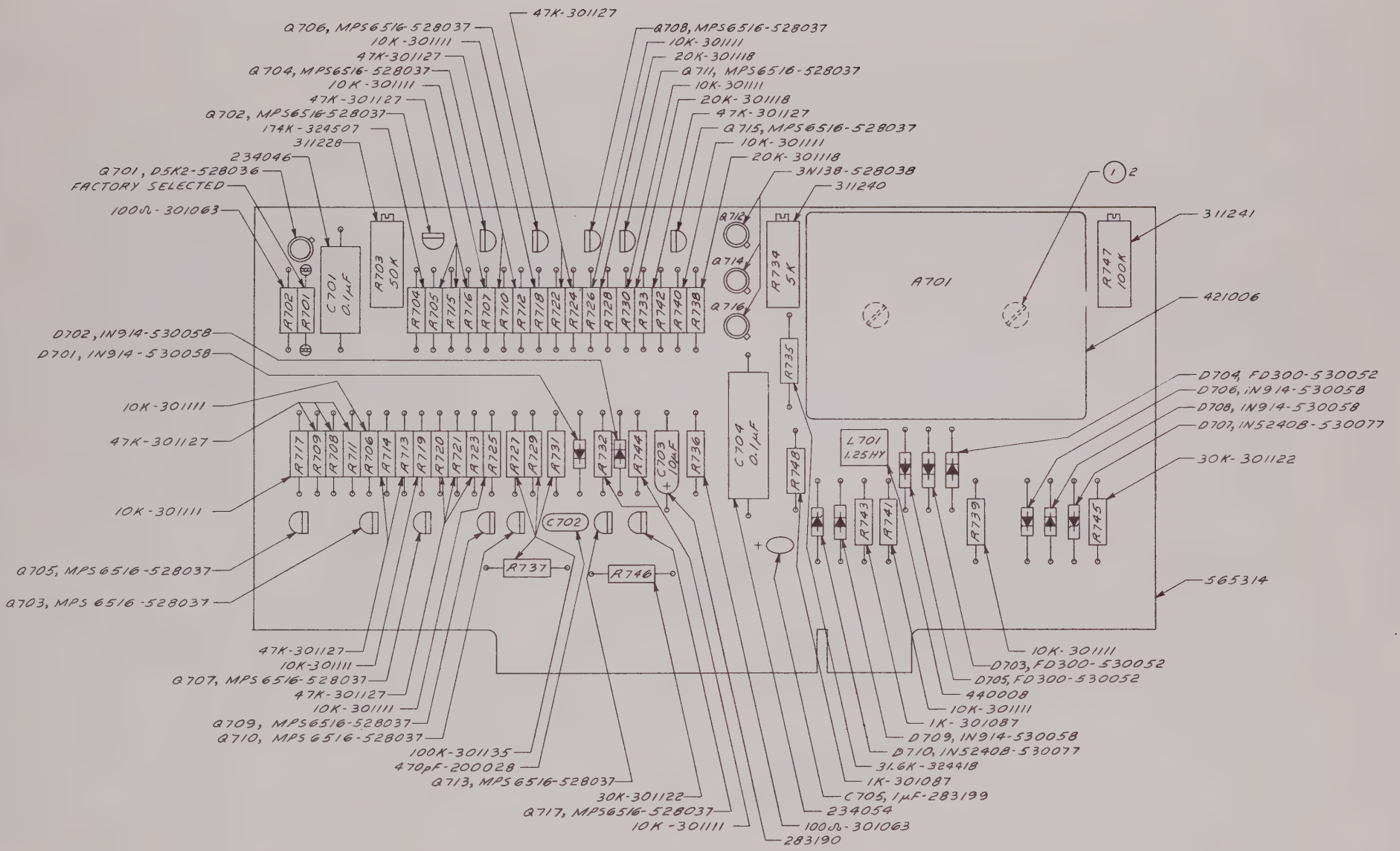


Figure 5-10. Capacitance Integrator Board, Parts Locations.

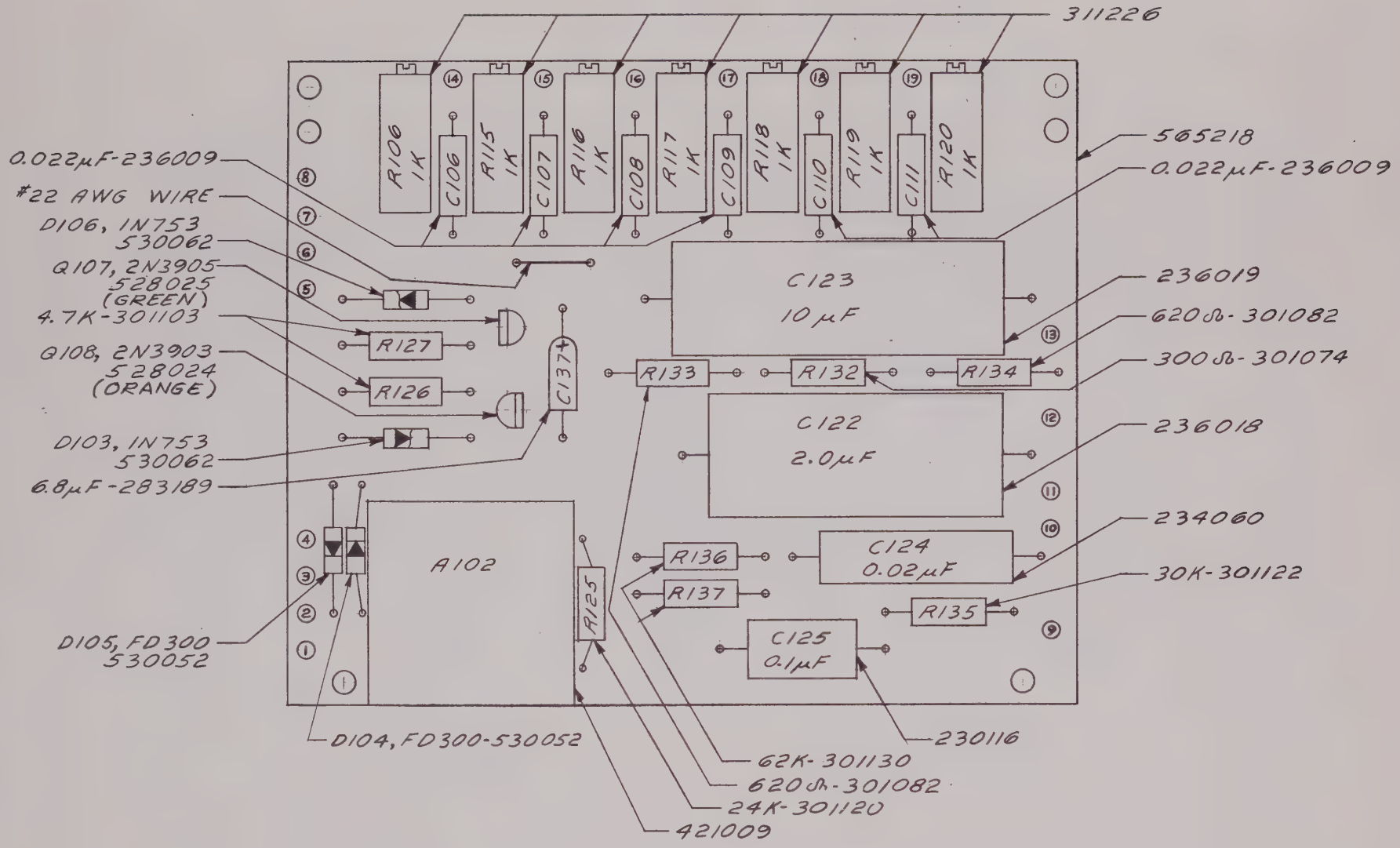


Figure 5-11. Input & Range Adj. Ampl. (Right Side), Parts Locations.

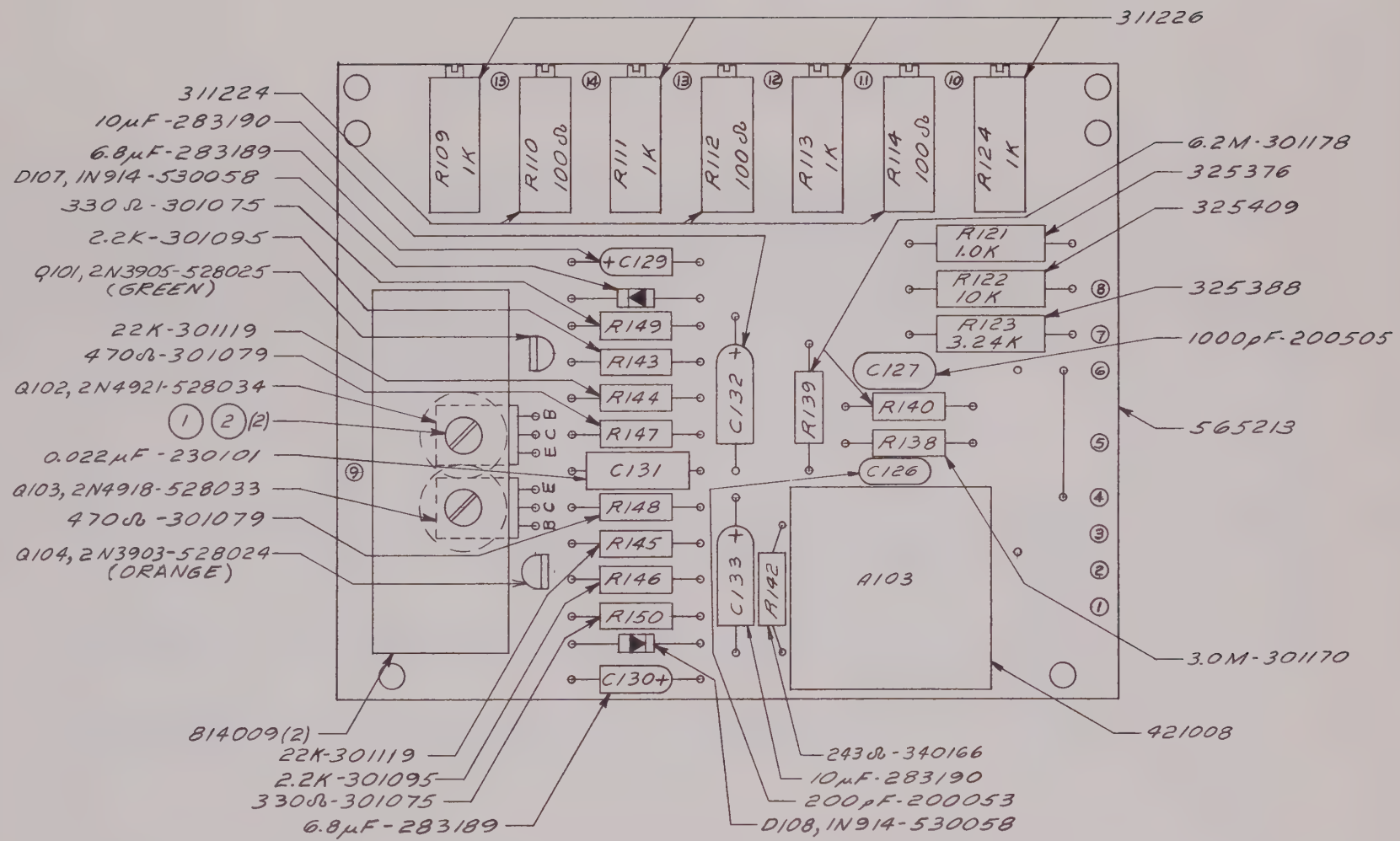


Figure 5-12. Input & Range Adj. Ampl. (Left Side), Parts Locations.

TABLE OF REPLACEABLE PARTS

FOR 71K

Reference	Description				BEC PART NO.
A101	Amplifier, Op.	Analog Devices No. 105C			421003
A102	Amplifier, Op.	Analog Devices No. 105C			421003
A103	Amplifier, Op.	Analog Devices No. 105C			421003
C101	Capacitor, Ceramic	10 pF	300V	5%	224129
C102	Capacitor, Air Var.	4 - 63 pF			275144
C103	Capacitor, Mylar	0.1 µF	200V	10%	234005
C104	Capacitor, Disc Ceramic	0.05 µF	100V	GMV	224117
C105	Capacitor, Disc Ceramic	0.05 µF	100V	GMV	224117
C106	Capacitor, Met. Mylar	0.022 µF	200V	10%	236009
C107	Capacitor, Met. Mylar	0.022 µF	200V	10%	236009
C108	Capacitor, Met. Mylar	0.022 µF	200V	10%	236009
C109	Capacitor, Met. Mylar	0.022 µF	200V	10%	236009
C110	Capacitor, Met. Mylar	0.022 µF	200V	10%	236009
C111	Capacitor, Met. Mylar	0.022 µF	200V	10%	236009
C112	Capacitor, Polystyrene	0.01 µF	100V	+0-2%	234055
C113	Capacitor, Mica	(factory selected)			
C114	Capacitor, Disc. Ceramic	0.05 µF	100V	GMV	224117
C115	Capacitor, Disc Ceramic	0.05 µF	100V	GMV	224117
C116	Capacitor, Disc Ceramic	0.05 µF	100V	GMV	224117
C117	Capacitor, Disc Ceramic	0.05 µF	100V	GMV	224117
C118	Capacitor, Disc Ceramic	0.05 µF	100V	GMV	224117
C119	Capacitor, Disc Ceramic	0.05 µF	100V	GMV	224117
C120	Capacitor, Disc Ceramic	0.05 µF	100V	GMV	224117
C121	Capacitor, Disc Ceramic	0.05 µF	100V	GMV	224117
C122	Capacitor, Polycarbonate	2 µF	200V	2%	236018
C123	Capacitor, Met. Mylar	10 µF	50V	10%	236019
C124	Capacitor, Polystyrene	0.02 µF	100V	2%	234060
C125	Capacitor, Met. Mylar	0.1 µF	200V	10%	230116
C126	Capacitor, Mica	200 pF	500V	2%	200053
C127	Capacitor, Mica	1000 pF	100V	5%	200507
C128	Not used				
C129	Capacitor, Tantalum	6.8 µF	6V	20%	283189
C130	Capacitor, Tantalum	6.8 µF	6V	20%	283189
C131	Capacitor, Mylar	0.022 µF	200V	10%	234040
C132	Capacitor, Tantalum	10 µF	20V	20%	283190
C133	Capacitor, Tantalum	10 µF	20V	20%	283190
C134	Capacitor, Disc Ceramic	0.05 µF	100V	GMV	224117
C135	Capacitor, Disc Ceramic	0.05 µF	100V	GMV	224117

Reference	Description				BEC PART NO.
C136	Capacitor, Disc Ceramic	0.05 µF	100V	GMV	224117
C137	Capacitor, Tantalum	6.8 µF	6V	20%	283189
C138	Capacitor, Disc Ceramic	0.05 µF	100V	20%	224117
C139	Capacitor, Disc Ceramic	0.05 µF	100V	20%	224117
C140	Capacitor, Electrolytic	1000 µF	50V	-10 +100	283201
C141	Capacitor, Electrolytic	1000 µF	50V	-10 +100	283201
C142	Capacitor, Trimmer	5000 pF	500V	1%	203014
C143	Capacitor, Var.	15 - 60 pF			281004
C201	Capacitor, Electrolytic	100 µF	25V		283105
C202	Capacitor, Met. Polycarb.	0.47 µF	200V	5%	236016
C203	Capacitor, Met. Polycarb.	0.33 µF	200V	5%	236015
C204	Capacitor, Tantalum	1 µF	35V	10%	283187
C205	Capacitor, Tantalum	1 µF	35V	10%	283187
C206	Capacitor, Tantalum	100 µF	10V	10%	283191
C207	Capacitor, Tantalum	100 µF	10V	10%	283191
C208	Capacitor, Mylar	(factory selected)			
C209	Capacitor, Mylar	(factory selected)			
C210	Capacitor, Mylar	.01 µF	200V	10%	234027
C211	Capacitor, Mica	30 pF	500V	1%	200057
C212	Capacitor, Electrolytic	1 µF	35V	10%	283187
C213	Capacitor, Electrolytic	100 µF	6V		283171
C214	Capacitor, Electrolytic	100 µF	6V		283171
C325	Capacitor, Mica	47 pF	500V	5%	200056
C326	Capacitor, Electrolytic	4.7 µF	35V	10%	283200
C327	Capacitor, Electrolytic	1 µF	35V	10%	283187
C404	Capacitor, Tantalum	10 µF	20V	20%	283190
C405	Capacitor, Tantalum	1 µF	35V	10%	283187
C406	Capacitor, Tantalum	1 µF	35V	10%	283187
C410	Capacitor, Tantalum	10 µF	20V	20%	283190
C501	Capacitor, Tantalum	10 µF	20V	20%	283190
C502	Capacitor, Mylar	0.1 µF	200V	10%	234005
C503	Capacitor, Mylar	0.056 µF	200V	20%	236006
C504	Capacitor, Tantalum	1.0 µF	35V	10%	283187
C505	Capacitor, Mica	100 pF	500V	5%	200001
C506	Capacitor, Ceramic	0.05 µF	100V	+80 -20%	224117
C507	Capacitor	680 pF	500V	1%	200503
C508	Capacitor	75 pF	500V	5%	200059
C509	Capacitor, Var	5.5-18 pF			281007

Reference	Description				BEC PART NO.
C601	Capacitor, Tantalum	1 μF	35V	10%	283187
C602	Capacitor, Mylar	0.01 μF	200V	10%	234027
C603	Capacitor, Tantalum	1 μF	35V	10%	283187
C604	Capacitor, Tantalum	1 μF	35V	10%	283187
C605	Capacitor, Tantalum	6.8 μF	6V	20%	283189
C606	Capacitor, Tantalum	1 μF	35V	10%	283187
C607	Capacitor, Tantalum	1 μF	35V	10%	283187
C608	Capacitor, Tantalum	1 μF	35V	10%	283187
C609	Capacitor, Disc Ceramic	0.05 μF	100V	GMV	224117
C701	Capacitor, Met. Polycarb.	0.1 μF	50V	10%	234046
C702	Capacitor, Mica	470 pF	300V	5%	200028
C703	Capacitor, Tantalum	10 μF	20V	20%	283190
C704	Capacitor, Polystyrene	0.1 μF	200V	5%	234054
C705	Capacitor, Tantalum	1 μF	35V	20%	283199
D101	Not used				
D102	Not used				
D103	Diode, 1N753	Silicon, Zener			530062
D104	Diode, FD300	Silicon, Low Leakage			530052
D105	Diode, FD300	Silicon, Low Leakage			530052
D106	Diode, 1N753	Silicon, Zener			530062
D107	Diode, 1N914	Silicon			530058
D108	Diode, 1N914	Silicon			530058
D109	Diode, 1N914	Silicon			530058
D110	Diode, 1N914	Silicon			530058
D111	Rectifier Bridge	S6211			532009
D201	Diode, 1N914	Silicon			530058
D202	Diode, 1N914	Silicon			530058
D203	Diode, 1N914	Silicon			530058
D401	Diode, 1N914	Silicon			530058
D402	Diode, 1N914	Silicon			530058
D403	Diode, 1N914	Silicon			530058

Reference		Description	BEC PART NO.
D404	Diode, 1N914	Silicon	530058
D405	Diode, 1N914	Silicon	530058
D406	Not used		
D407	Diode, 1N914	Silicon	530058
D501	Diode, 1N755A	Silicon, Zener	530066
D502	Diode, FD300	Silicon, Low Leakage	530052
D503	Diode, FD300	Silicon, Low Leakage	530052
D504	Diode, FD300	Silicon, Low Leakage	530052
D505	Diode, 1N914	Silicon	530058
D506	Diode, 1N914	Silicon	530058
D507	Diode, 1N914	Silicon	530058
D508	Diode, 1N755A	Silicon, Zener	530066
D509	Diode, 1N755A	Silicon, Zener	530066
D510	Diode, 1N914	Silicon	530058
D511	Diode, 1N914	Silicon	530058
D601	Diode, 1N827	Silicon, Reference Zener	530072
D602	Diode, 1N914	Silicon	530058
D603	Diode, 1N914	Silicon	530058
D604	Diode, 1N914	Silicon	530058
D701	Diode, 1N914	Silicon	530058
D702	Diode, 1N914	Silicon	530058
D703	Diode, FD300	Silicon, Low Leakage	530052
D704	Diode, FD300	Silicon, Low Leakage	530052
D705	Diode, FD300	Silicon, Low Leakage	530052
D706	Diode, 1N914	Silicon	530058
D707	Diode, Zener 1N5240B	500 MW 10V 5%	530077
D708	Diode, 1N914	Silicon	530058
D709	Diode, 1N914	Silicon	530058
D710	Diode, Zener 1N5240B	500 MW 10V 5%	530077
J101	Receptacle	BNC Panel Mount	479123
J102	Receptacle	BNC Panel Mount	479123
J103	Receptacle	BNC Panel Mount	479123
J104	Receptacle	BNC Panel Mount	479123
J105	Receptacle	BNC Ins. Panel Mount	479165
J106	Receptacle	BNC Ins. Panel Mount	479165
J107	Receptacle	BNC Ins. Panel Mount	479165

Reference		Description		BEC PART NO.
J108	Receptacle	BNC Ins. Panel Mount		479165
J109	Connector	Cinch-Jones S-315-EB		479172
J110	Connector	Amphenol 165-15		477168
J111	Receptacle	22 Pos. Card-edge Connector		479173
J112	Receptacle	22 Pos. Card-edge Connector		479173
J113	Receptacle	22 Pos. Card-edge Connector		479173
J114	Receptacle	22 Pos. Card-edge Connector		479173
J115	Receptacle	22 Pos. Card-edge Connector		479173
J116	Receptacle	22 Pos. Card-edge Connector		479173
L201	Inductor, Toroid	120 mH ±1%		400137
L401	Inductor,	1.25 H - Stancor PCT 117		440008
L601	Inductor	1.25 H - Stancor PCT 117		440008
L602	Inductor	1.25 H - Stancor PCT 117		440008
L701	Inductor	1.25 H - Stancor PCT 117		440008
M101	Meter	0 - 190 μA		554190
Q101	Transistor, Silicon	PNP	2N3905	528025
Q102	Transistor, Silicon	NPN	2N4921	528034
Q103	Transistor, Silicon	PNP	2N4918	528033
Q104	Transistor, Silicon	NPN	2N3903	528024
Q105	Not used			
Q106	Not used			
Q107	Transistor, Silicon	PNP	2N3905	528025
Q108	Transistor, Silicon	NPN	2N3903	528024
Q201	Transistor, Silicon	PNP	2N3905	528025
Q202	Transistor, Silicon	PNP	2N3905	528025
Q203	Transistor, Silicon	NPN	2N3903	528024
Q204	Transistor, Silicon	NPN	2N697	528015
Q205	Transistor, Silicon	NPN	2N697	528015
Q206	Transistor, Silicon	NPN	2N3903	528024
Q207	Transistor, silicon	NPN	2N3903	528024

Reference	Description			BEC PART NO.
Q325	Transistor		2N4918	528033
Q326	Transistor		2N4918	528033
Q401	Transistor, Silicon	PNP	2N3905	528025
Q402	Transistor, Silicon	PNP	2N3905	528025
Q403	Transistor, Array		RCA CA 3018	528027
Q404	Transistor, Array		RCA CA 3018	528027
Q405	Transistor, Silicon	PNP	2N3905	528025
Q406	Transistor, Silicon	NPN	2N3903	528024
Q407	Not used			
Q408	Transistor, J FET	N Ch.	2N3819	528022
Q409	Transistor, J FET	N Ch.	2N3819	528022
Q410	Not used			
Q411	Transistor, Silicon	NPN	2N3903	528024
Q501	Transistor, MOS FET	N Ch.	3N138	528035
Q502	Transistor, J FET	N Ch.	2N5459	528019
Q503	Transistor, J FET	N Ch.	2N5459	528019
Q504	Transistor, Silicon	NPN	2N3903	528024
Q505	Transistor, J FET	N Ch.	2N5459	528019
Q506	Transistor, J FET	N Ch.	2N5459	528019
Q507	Transistor, J FET	N Ch.	2N5459	528019
Q601	Transistor, Array		CA3018	528027
Q602	Transistor, Silicon	NPN	2N3903	528024
Q603	Transistor, Silicon	PNP	2N3905	528025
Q604	Transistor, Silicon	PNP	2N3905	528025
Q605	Transistor, Array		CA3018	528027
Q606	Transistor, Silicon	PNP	2N3905	528025
Q607	Transistor, Silicon	PNP	2N3905	528025
Q608	Transistor, Silicon	NPN	2N3903	528024
Q609	Transistor, Silicon	PNP	2N3905	528025
Q701	Transistor, Unijunction	GE D5K2		528036
Q702	Transistor, Silicon PNP	Mot. MPS 6516		528037
Q703	Transistor, Silicon PNP	Mot. MPS 6516		528037
Q704	Transistor, Silicon PNP	Mot. MPS 6516		528037
Q705	Transistor, Silicon PNP	Mot. MPS 6516		528037
Q706	Transistor, Silicon PNP	Mot. MPS 6516		528037
Q707	Transistor, Silicon PNP	Mot. MPS 6516		528037
Q708	Transistor, Silicon PNP	Mot. MPS 6516		528037
Q709	Transistor, Silicon PNP	Mot. MPS 6516		528037

Reference	Description				BEC PART NO.
Q710	Transistor, Silicon PNP	Mot. MPS 6516			528037
Q711	Transistor, Silicon PNP	Mot. MPS 6516			528037
Q712	Transistor, MOS - FET	3N138			528035
Q713	Transistor, Silicon PNP	Mot. MPS 6516			528037
Q714	Transistor, MOS- FET	3N138			528035
Q715	Transistor, Silicon PNP	Mot. MPS 6516			528037
Q716	Transistor, MOS - FET	3N138			528035
Q717	Transistor, Silicon PNP	Mot. MPS 6516			528037
R106	Resistor, Var.	1 KΩ	3/4W	10%	311226
R107	Resistor, Comp.	620	1/2W	5%	301082
R108	Resistor, Comp.	62 KΩ	1/2W	5%	301130
R109	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R110	Resistor, Var. Cermet	100 Ω	3/4W	10%	311224
R111	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R112	Resistor, Var. Cermet	100 Ω	3/4W	10%	311224
R113	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R114	Resistor, Var. Cermet	100 Ω	3/4W	10%	311224
R115	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R116	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R117	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R118	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R119	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R120	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R121	Resistor, Metal Film RN65C	1 KΩ	1/4W	1%	325376
R122	Resistor, Metal Film RN65C	10.0 KΩ	1/4W	1%	325409
R123	Resistor, Metal Film RN65C	3.14 KΩ	1/4W	1%	325388
R124	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R125	Resistor, Comp.	24 KΩ	1/2W	5%	301120
R126	Resistor, Comp.	4.7 KΩ	1/2W	5%	301103
R127	Resistor, Comp.	4.7 KΩ	1/2W	5%	301103
R128	Resistor, Comp.	(factory selected)			
R129	Resistor, Metal Film RN65D	162 Ω	1/4W	1%	315066
R130	Resistor, Comp.	300 Ω	1/2W	5%	301074
R131	Resistor, Comp.	10 KΩ	1/4W	10%	325409
R132	Resistor, Comp.	300 Ω	1/2W	5%	301074
R133	Resistor, Comp.	620 Ω	1/2W	5%	301082
R134	Resistor, Comp.	620 Ω	1/2W	5%	301082
R135	Resistor, Comp.	30 KΩ	1/2W	5%	301122
R136	Resistor, Comp.	62 KΩ	1/2W	5%	301130
R137	Resistor, Comp.	62 KΩ	1/2W	5%	301130
R138	Resistor, Comp.	3 M	1/2W	5%	301170
R139	Resistor, Comp.	6.2 M	1/2W	5%	301178
R140	Resistor, Comp.	6.2 M	1/2W	5%	301178
R141	Not used				
R142	Resistor, Comp.	243Ω	3/8W	1%	340166

Reference	Description				BEC PART NO.
R143	Resistor, Comp.	2.2 KΩ	1/2W	5%	301095
R144	Resistor, Comp.	22 KΩ	1/2W	5%	301119
R145	Resistor, Comp.	22 KΩ	1/2W	5%	301119
R146	Resistor, Comp.	2.2 KΩ	1/2W	5%	301095
R147	Resistor, Comp.	470 Ω	1/2W	5%	301079
R148	Resistor, Comp.	470 Ω	1/2W	5%	301079
R149	Resistor, Comp.	330 Ω	1/2W	5%	301075
R150	Resistor, Comp.	330 Ω	1/2W	5%	301075
R151	Resistor, Comp	100 KΩ	1/2W	5%	301135
R201	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R202	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R203	Resistor, Comp.	1 KΩ	1/2W	5%	301087
R204	Resistor, Comp.	20 KΩ	1/2W	5%	301118
R205	Resistor, Comp.	20 KΩ	1/2W	5%	301118
R206	Resistor, Comp.	5.1 KΩ	1/2W	5%	301104
R207	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R208	Resistor, Comp.	100 KΩ	1/2W	5%	301135
R209	Resistor, Comp.	20 KΩ	1/2W	5%	301118
R210	Resistor, Comp.	43 KΩ	1/2W	5%	301126
R211	Resistor, Comp.	6.8 KΩ	1/2W	5%	301107
R212	Resistor, Comp.	120 Ω	1/2W	5%	301065
R213	Resistor, Comp.	15 KΩ	1/2W	5%	301115
R214	Resistor, Comp.	7.5 KΩ	1/2W	5%	301108
R215	Resistor, Comp.	1.1 KΩ	1/2W	5%	301088
R216	Resistor, Comp.	120 Ω	1/2W	5%	301065
R217	Resistor, Comp.	6.8 KΩ	1/2W	5%	301107
R218	Resistor, Comp.	20 KΩ	1/2W	5%	301118
R219	Resistor, Comp.	43 KΩ	1/2W	5%	301126
R220	Resistor, Comp.	1.1 KΩ	1/2W	5%	301088
R221	Resistor, Comp.	120 Ω	1/2W	5%	301065
R222	Resistor, Comp.	6.8 KΩ	1/2W	5%	301107
R223	Resistor, Comp.	43 KΩ	1/2W	5%	301126
R325	Resistor	2.43 KΩ	1/4W	1%	325385
R326	Resistor	3 Ω	1/2W	5%	301504
R327	Resistor	3 Ω	1/2W	5%	301504
R328	Resistor	3 Ω	1/2W	5%	301504
R329	Resistar, Var.	5 KΩ	3/4W	10%	311240
R330	Resistor	4.99 KΩ	1/4W	1%	325394
R331	Resistor	16.5 KΩ	1/4W	1%	325450
R332	Resistor	1.58 KΩ	1/4W	1%	325378
R333	Resistor, Var.	1 KΩ	3/4W	10%	311226

Reference	Description				BEC PART NO.
R401	Resistor, Comp.	20 KΩ	1/2W	5%	301118
R402	Resistor, Comp.	270 KΩ	1/2W	5%	301145
R403	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R404	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R405	Resistor, Comp.	33 KΩ	1/2W	5%	301123
R406	Resistor, Comp.	33 KΩ	1/2W	5%	301123
R407	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R408	Resistor, Comp.	33 KΩ	1/2W	5%	301123
R409	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R410	Resistor, Comp.	1.1 KΩ	1/2W	5%	301088
R411	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R412	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R413	Resistor, Comp.	33 KΩ	1/2W	5%	301123
R414	Resistor, Comp.	33 KΩ	1/2W	5%	301123
R415	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R416	Resistor, Comp.	33 KΩ	1/2W	5%	301123
R417	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R418	Resistor, Comp.	27 KΩ	1/2W	5%	301121
R419	Resistor, Comp.	2 KΩ	1/2W	5%	301094
R420	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R421	Resistor, Comp.	220 Ω	1/2W	5%	301071
R422	Resistor, Comp.	100 KΩ	1/2W	5%	301135
R423	Resistor, Comp.	270 KΩ	1/2W	5%	301145
R424	Resistor, Comp.	220 Ω	1/2W	5%	301071
R425	Not used				
R426	Not used				
R427	Resistor, Metal Film RN65C	499 Ω	1/4W	5%	325299
R428	Not used				
R429	Resistor, Comp.	100 KΩ	1/2W	5%	301135
R501	Resistor, Comp.	30 KΩ	1/2W	5%	301122
R502	Resistor, Comp.	24 KΩ	1/2W	5%	301120
R503	Resistor, Comp.	24 KΩ	1/2W	5%	301120
R504	Resistor, Comp.	150 KΩ	1/2W	5%	301139
R505	Resistor, Comp.	150 KΩ	1/2W	5%	301139
R506	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R507	Resistor, Comp.	100 KΩ	1/2W	5%	301135
R508	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R509	Resistor, Comp.	4.7 M	1/2W	5%	301175
R510	Resistor, Comp.	1 M	1/2W	5%	301159
R511	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R512	Resistor, Comp.	4.7 KΩ	1/2W	5%	301103
R513	Resistor, Metal Film RN65C	10 KΩ	1/4W	1%	325409
R514	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R515	Resistor, Comp.	100 KΩ	1/2W	5%	301135
R516	Resistor, Metal Film RN65C	10 KΩ	1/4W	1%	325409

Reference	Description				BEC PART NO.
R517	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R518	Resistor, Metal Film RN65C	4.99 KΩ	1/4W	1%	325394
R519	Resistor, Metal Film RN65C	4.99 KΩ	1/4W	1%	325394
R520	Resistor, Comp.	100 KΩ	1/2W	5%	301135
R521	Resistor, Metal Film RN65C	54.9 KΩ	1/4W	1%	325467
R522	Resistor, Metal Film RN65C	499 KΩ	1/4W	1%	325662
R523	Resistor, Comp.	24 KΩ	1/2W	5%	301120
R524	Resistor, Comp.	24 KΩ	1/2W	5%	301120
R525	Resistor, Comp.	1 KΩ	1/2W	5%	301087
R526	Resistor, Metal Film RN65C	10 KΩ	1/4W	1%	325409
R527	Resistor, Metal Film RN65C	1.78 KΩ	1/4W	1%	325379
R528	Resistor, Comp.	9.1 KΩ	1/2W	5%	301110
R529	Resistor, Comp.	1 M	1/2W	5%	301159
R530	Resistor, Comp.	9.1 KΩ	1/2W	5%	301110
R601	Resistor, Metal Film RN65C	267 Ω	1/4W	1%	325253
R602	Resistor, Var. Cermet	500 Ω	3/4W	10%	311225
R603	Resistor, Comp.	27 KΩ	1/2W	5%	301121
R604	Resistor, Comp.	27 KΩ	1/2W	5%	301121
R605	Resistor, Comp.	43 KΩ	1/2W	5%	301126
R606	Resistor, Comp.	22 Ω	1/2W	5%	301047
R607	Resistor, Metal Film RN65C	2.8 KΩ	1/4W	1%	325386
R608	Resistor, Comp.	270 KΩ	1/2W	5%	301145
R609	Resistor, Var. Cermet	2 KΩ	3/4W	10%	311227
R610	Resistor, Metal Film RN65C	5.23 KΩ	1/4W	1%	325396
R611	Resistor, Comp.	22 Ω	1/2W	5%	301047
R612	Resistor, Comp.	1 KΩ	1/2W	5%	301087
R613	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R614	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R615	Resistor, Comp.	220 Ω	1/2W	5%	301071
R616	Resistor, Comp.	220 Ω	1/2W	5%	301071
R617	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R618	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R619	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R620	Resistor, Comp.	22 M	1/2W	5%	301191
R621	Resistor, Comp.	33 KΩ	1/2W	5%	301123
R622	Resistor, Comp.	33 KΩ	1/2W	5%	301123
R623	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R624	Resistor, Comp.	33 KΩ	1/2W	5%	301123
R625	Resistor, Comp.	4.7 M	1/2W	5%	301175
R626	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R627	Resistor, Comp.	4.7 KΩ	1/2W	5%	301103
R628	Resistor, Comp.	100 KΩ	1/2W	5%	301135
R629	Resistor, Comp.	200 KΩ	1/2W	5%	301142
R630	Resistor, Comp.	100 KΩ	1/2W	5%	301135
R631	Resistor, Comp.	4.7 KΩ	1/2W	5%	301103

Reference	Description				BEC Part No.
R632	Resistor, Comp.	3.3 KΩ	1/2W	5%	301099
R633	Resistor, Metal Film RN65C	4.53	1/4W	1%	325390
R634	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R635	Resistor, Metal Film RN65C	1.00 KΩ	1/4W	1%	325376
R636	Resistor, Metal Film RN65C	9.09 KΩ	1/4W	1%	325407
R637	Resistor, Var. Cermet	1 KΩ	3/4W	10%	311226
R701	(factory selected)				
R702	Resistor, Comp.	100 Ω	1/2W	5%	301063
R703	Resistor, Var. Cermet	50 KΩ	3/4W	10%	311228
R704	Resistor,	174 KΩ	1/8W	1%	324507
R705	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R706	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R707	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R708	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R709	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R710	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R711	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R712	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R713	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R714	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R715	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R716	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R717	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R718	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R719	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R720	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R721	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R722	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R723	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R724	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R725	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R726	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R727	Resistor, Comp.	100 KΩ	1/2W	5%	301135
R728	Resistor, Comp.	20 KΩ	1/2W	5%	301118
R729	Resistor, Comp.	100 KΩ	1/2W	5%	301135
R730	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R731	Resistor, Comp.	100 KΩ	1/2W	5%	301135
R732	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R733	Resistor, Comp.	20 KΩ	1/2W	5%	301118
R734	Resistor, Var. Cermet	5 KΩ	3/4Ω	10%	311240
R735	Resistor,	31.6 KΩ	1/8W	1%	324418
R736	Resistor, Comp.	100 Ω	1/2W	5%	301063
R737	Resistor, Comp.	100 KΩ	1/2W	5%	301135
R738	Resistor, Comp.	20 KΩ	1/2W	5%	301118
R739	Resistor, Comp.	10 KΩ	1/2W	5%	301111

Reference		Description			BEC Part No.
R740	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R741	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R742	Resistor, Comp.	47 KΩ	1/2W	5%	301127
R743	Resistor, Comp.	1 KΩ	1/2W	5%	301087
R744	Resistor, Comp.	10 KΩ	1/2W	5%	301111
R745	Resistor, Comp.	30 KΩ	1/2W	5%	301122
R746	Resistor, Comp.	30 KΩ	1/2W	5%	301122
R747	Resistor, Var. Cermet	100 KΩ	3/4W	5%	311241
R748	Resistor, Comp.	1 KΩ	1/2W	5%	301087
S101	Switch, C Range				465126
S102	Switch, D Range				465127
S103	Switch, Toggle, SPST				465109
T101	Transformer, Audio	UTC No. A23			445103
T102	Transformer, Audio	UTC No. A11			445102
T103	Transformer, PWN				446047
F301	Fuse, 0.25A (Slo-Blo)	117V	OR		545511
F301	Fuse, 1/8 A (Slo-Blo)	234V			545516
1301	Pilot Light NE2D				545108
A501	Amplifier, Op.	Analog Devices	421		421003
A502	Amplifier, Op.	Analog Devices			421003
A503	Amplifier, Op.	Analog Devices			421003
A504	Amplifier, Op.	Analog Devices			421003
A701	Amplifier, Op.	Burr-Brown No. 3012/25			421005